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AVIONICS READINESS PROGRAM FOR 1980-2000

DEVELOPED FOR
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VOLUME I GENERAL PLAN

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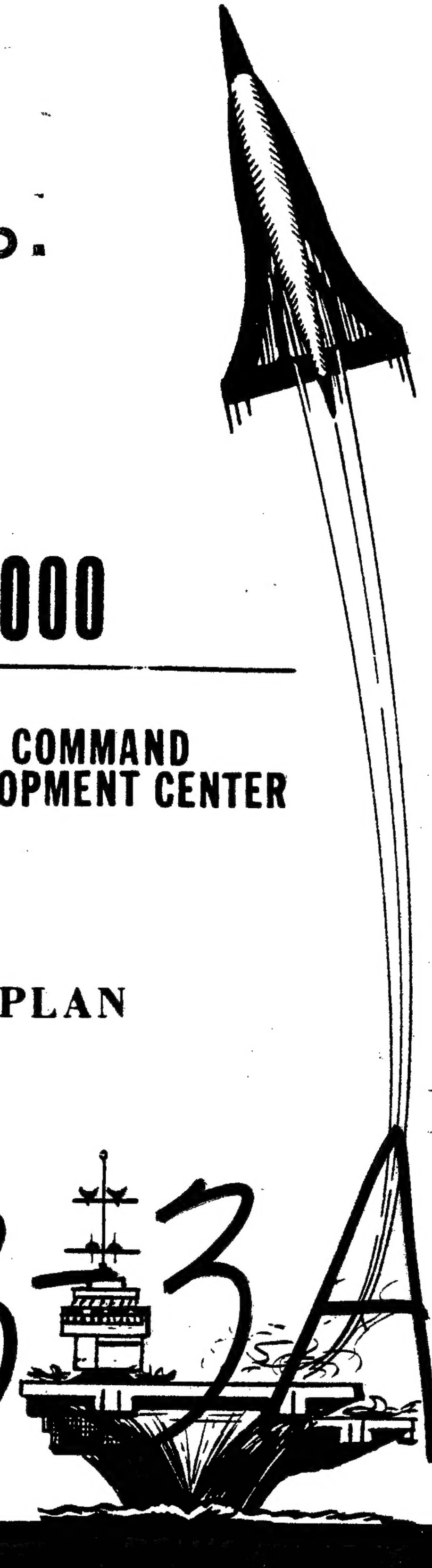

Naval Air Development Center
Warminster, Pennsylvania 18974

AVIONICS READINESS PROGRAM

FOR

1980 to 2000

VOLUME I

GENERAL PLAN

AVIONICS READINESS

- FOREWARD -

The Readiness factors being experienced on Navy air weapons systems which contain modern and complex technology avionics, are marginal at best. The current investment, in both manpower and material, that comprise the support for these systems is enormous. The prospect of large increases in the support investment to maintain the Readiness at status quo or to achieve only incremental improvement is alarming.

The high cost of readiness today can be traced to the current weapons systems planning, development and acquisition process. This process fails to prioritize the support requirement in the design and procurement phases. In the development community, a large imbalance exists between the priority of performance and the priority of support.

The life cycle cost of support for any given suite of avionics is essentially fixed during the 12-24 month period of Contract Definition or Engineering Development. It is during this period that the irreversible 10-20 year maintenance and support, life characteristic is established. The developers involved during this period do not provide or are not provided with specific and quantized direction, goals, limits, or requirements with respect to the support objective. By contrast, the operational and performance objectives are stated in extreme detail and absolute requirement. The avionic end item is not bought unless the performance of that item is satisfactorily demonstrated to the requirements of the specification.

A quick review of current procurement specifications will reveal that avionics support features, required by the specifications, are either nonexistent, brief or very general. Here and there, are found project

offices, isolated developments, and occasional laboratory efforts that are sensitive to, and articulate in stating the support requirement in the avionic specification. However, due to the low support priority in the early phases, the majority of the avionics development and procurement communities do not demonstrate the capability to state the Avionics Supportability requirement, except in general terms. There is no effective support for avionics unless specifically designed for support.

The success that has been achieved in obtaining performance suggests that similar success can be achieved in obtaining supportability by applying the same methods of precise and detailed requirements, and satisfactory demonstration of those supportability features prior to acceptance.

Dramatic Avionic Readiness improvements and reduced support costs can be achieved in next generation weapon systems by:

a. Including critically selected test, maintenance and support features, as an integral part of the avionics end item.

b. Performing simultaneous development, of the avionics end item and all material and soft elements that form its support system, under a common design regime and to common cost goals.

c. Requiring demonstration of the supportability of the avionics end item prior to acceptance.

Avionics that can be effectively supported at low cost are still in the future. The planning that is necessary to assure that "design for support" is incorporated to its full potential in future avionics, is required now. The full impact of such planning and related developments

will not broadly effect fleet readiness and support capability for several years. Indeed the restructuring of development priorities to include supportability as an avionics parameter, promises to be an arduous road.

In the preparation of this plan for the years 1980 to 2000, there was the great tendency to dwell on the problems of today's avoionics and test systems and make recommendations for near term, quick payoff programs. For it is after all, the present and near past that establishes our priorities. It was necessary to establish the conscious objective of organizing a program that systematically approaches far future and uncertain problems. The far future for electronics may be relatively near in time, 8-10 calendar years, but is "quite distant" when measured as one or more generations of technology.

Many of the approaches taken are based on problems that plague us today, with the idea in mind that we should not let history repeat itself and therefore, experience the same problems in the future for the same reasons. It is implied here that many of today's Readiness and Support problems are rooted in the organization of things rather than in limitations and/or deficiencies of current technology. This category of problems is amenable to near term improvement. It is suggested that certain efforts described herein have potential for near term payoff as well as the far technical future.

It is not known if the approach taken in this plan will have sufficient impact on future Avionics Readiness; certainly it will have some, perhaps quite a lot. The essential direction of the plan is to include an increased capability for test and repair in the avionics end item, to the limits and advantage that the emerging and future technology will allow. By this device all subsequent levels of test and repair should be greatly simplified. On the

other hand, history demonstrates that the introduction of any new technology has resulted in larger, more complex, costlier and in many respects less efficient support systems. How then can we gain comfort and be assured that the approach we are taking will reverse the established trend of increased support complexity? How can we prevent being overtaken by the same circumstance, events and weaknesses that have accompanied past generations of technology? Perhaps we cannot: but we have a plan and an approach that attempts to anticipate the Readiness problems of future aircraft in a more comprehensive way than in the past.

The plan is new and in itself requires development, change and maturity. It is by no means complete nor entirely accurate, nor does it contain much original thought. We believe, however, that it does contain the basic elements and organization necessary to have limited impact in the near term and extensive impact in the next generations of Avionics.

SUMMARY

The two volumes of the Avionics Readiness Program plan detail the broad areas of development work required in the current time frame to anticipate and properly prepare for the technological impact that 3rd and 4th generation avionic devices and systems will have on Avionics Readiness.

Good planning and plan execution can result in an exploitation of the inherent advantages that advanced technologies offer to the Readiness and Support disciplines. Presumably the next generations of avionics could require substantially less material and manpower investment in the support areas than current avionics systems require. Neglect of a planned approach may result in a Readiness and Support capability no better than than which is experienced today.

This plan addresses the problem of improved Readiness in the 1980 to 2000 year period. The approach taken by this plan requires a large degree of freedom to attack the problem. Payoff periods are far enough in advance that present day procedures and limitations need not adversely affect future Readiness capability.

The Electronics-X[1] study emphasises the magnitude of the current Readiness and Support problem, details findings relative to these problems, and makes broad high level recommendation concerning changes in procurement and support policies and procedures. The Avionics Readiness Program as presented in this plan addresses many of the same issues as Electronics-X, and while there may be agreement on issues, there is not necessarily concurrence on recommended solutions. Since the Avionics Readiness Program deals with advanced technologies it is recommended that certain basic

1 Electronics-X: A Study of Military Electronics with Particular Reference to Cost and Reliability. IDA Report R-195, Jan 1974

development work be accomplished prior to implementation of wide policy changes, particularly as they may affect future weapon systems Readiness and Support.

The task areas proposed by this plan are based on the following tenets:

a. The design of the avionics end item is the control element in the determination of all subsequent levels of support and Readiness capability. Irreversible life cycle Readiness capability and support requirements are established at the Avionics design table.

b. The design of the Readiness and Support system and all related elements must be performed simultaneously with the design of the avionics end item, and both should be performed under a common architecture and regime.

c. All design of Avionics end items and associated Readiness and Support systems must be performed to a common cost objective.

d. Support and Readiness requirements should be subjected to the same degree of detail and quantization in the Avionics specification as the function and performance parameters. Measurement, evaluation and acceptance of the Readiness and Support function in Avionics should be executed to the same rules and degree as the functional and performance parameters.

The issues and task areas contained herein are interrelated and propose to explore some of the broad issues of Electronics X as well as smaller issues which are relavent to Naval Avionics Readiness. Electronics X only recommends solutions; it does not propose an implementation to achieve these solutions. The implementations recommended in the Avionics Readiness Plan make it complementary to Electronics X.

Figure 1 is a structured representation of work efforts and organization of efforts contained in this plan.

The efforts addressed by the Avionics Readiness Program are broad in scope, addressing basic technology, weapons systems, test systems, specifications of Avionics and Avionics support, and cost effectiveness of avionic systems. The work is related in time and function.

The plan provides a structured framework of required developments and related work activity, suitable for planning an integrated Navy laboratory and field activity assault on the Readiness problem.

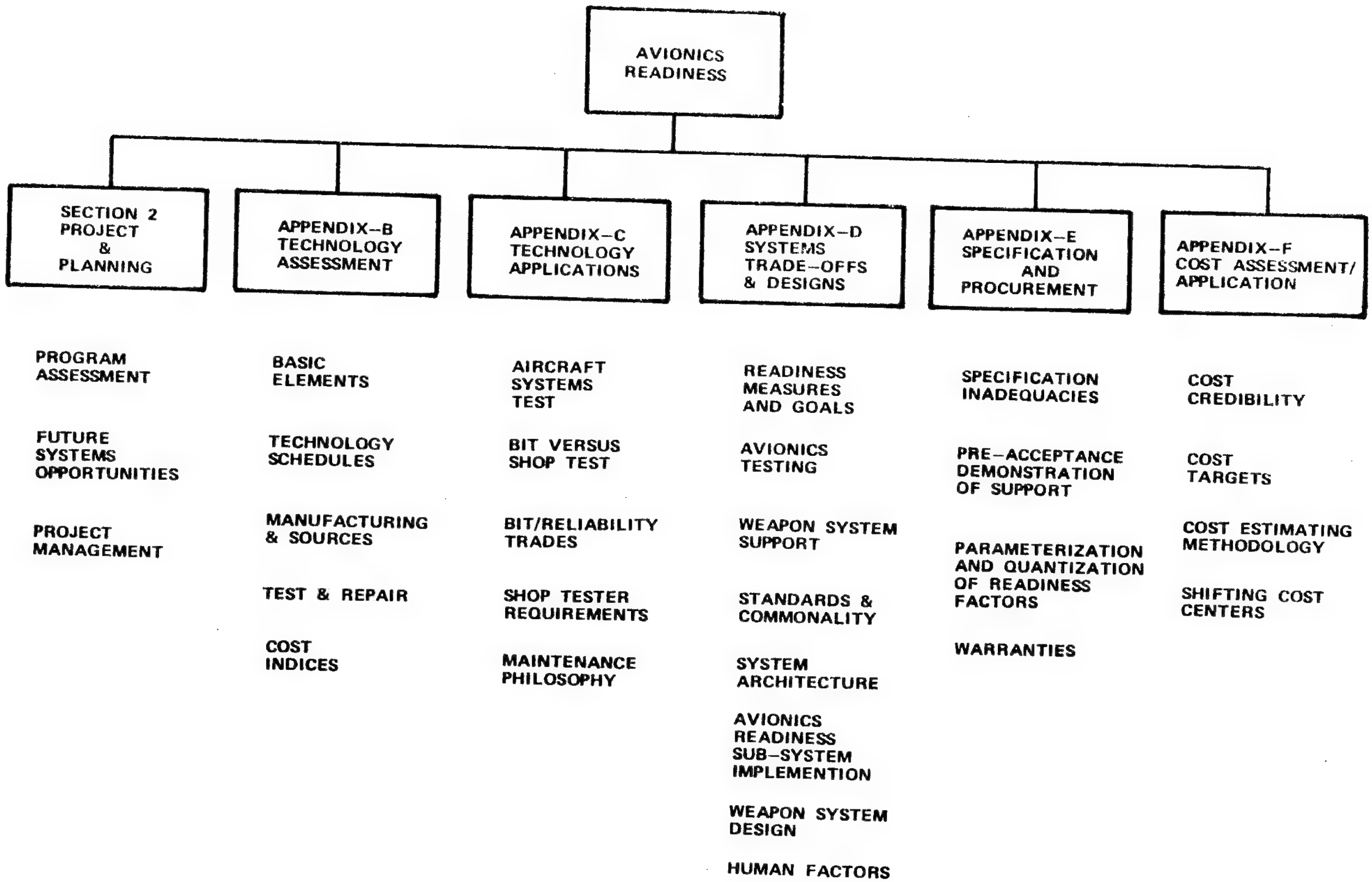

Fig 1 Avionics Readiness Program, Task Organization

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SECTION I

PROGRAM DESCRIPTION

1.0 INTRODUCTION - The AVIONICS READINESS PROGRAM for the years 1980 to 2000 was developed by NAVAL AIR DEVELOPMENT CENTER, Code 50 for NAVAL AIR SYSTEMS COMMAND, Code AIR 340E. All work contained in this plan was developed under AIRTASK A3400000/001B/5F41461408, dated 11 November 1974 and entitled "AVIONICS READINESS".

The plan is presented in two volumes:

VOLUME I	GENERAL PLAN
VOLUME II	IMPLEMENTATION PLAN

The general plan is extremely broad in scope and is admittedly larger than the specific objectives of the AIRTASK. It was felt necessary, however, to propose such a broad program in order to arrive at a final set of requirements and tasks that are appropriately related to each other and to the support problem in general. The selection of subjects in the plan was influenced to a large extent by the Electronics-X study.

The plan is structured so that all work tasks proposed and scheduled are coordinated with each other and with future weapon systems applications, and can be implemented in total should Navy management so choose.

The use of words that imply particular technique and/or application are avoided in the plan. For example, "BITE" is often thought of as unique equipment contained in a WRA but totally separate from the main function of the assembly. "Software" carries with it many preconceptions and prejudicies.

Phrases such as "self contained test" are used throughout the plan as they do not imply either a hardware or software implementation, nor do they imply any particular degree of integration between prime avionic functions and test functions.

General terminology is preferred, since the exact nature of test implementation in future avionics has not yet been determined. The future role to be played by hardware, software, firmware or hybrid device should not be pre-established because of semantics or current biases.

1.1 Airtask Objective - The objective of the Airtask is to develop a long range plan for the improvement of Avionics Readiness in the 1980-2000 year time period. To attain this end, the Airtask directs that the plan include an assessment of future operational requirements, airborne and test systems and related logistic support elements, and recommendations on areas requiring development and their scope.

Guidance - As guidance to achieve the objective of the Airtask, three specific areas of interest were identified:

a. Technology Assessment/Forecast - determine the direction and speed of technology growth and its impact on future systems and systems diagnostics.

b. Future Operational Requirements - review long range weapon systems planning to determine those programs which can be impacted by the Avionics Readiness Program.

c. Diagnostics Maintenance - identify requirements for diagnostic procedure development, packaging for maintenance, and inter-system fault detection.

1.2 Goals and Objectives - The primary goal of the Avionics Readiness effort is to establish the basis for cost effective support of Avionic systems which will be introduced into fleet service in the 1980 to 2000 year period. The effort will impact the development of avionics and

their related support systems to the extent that skills and material required to support those systems can be predetermined, maintained, and bounded. Successful completion of this program should result in a practical Design to Cost or Life Cycle Cost capability in Avionic systems acquisition.

In pursuit of this goal several general objectives are established:

a. Evaluate all applications of advanced technology devices. In this regard, manufacturing process, cost indices, second and third source potentials, material and yield, major markets, and technical characteristics will be investigated, documented and related to weapons systems procurement schedules. Emphasis will be placed on failure, test and repair modes for each technology application.

b. Application of advanced technologies to subsystems and required test systems will be developed. Detailed in-circuit and in-system test requirements and techniques will be developed. Where a fully self contained test and maintenance capability cannot be achieved, the appropriate shop test and repair requirement will be determined. Where necessary, actual development of avionic equipment and support demonstrations will be implemented.

c. Applications of advanced technology to future weapons systems will be developed. Cost effectiveness measures for whole weapons systems and their support will be developed. Tradeoffs between avionics capabilities, test requirements at all locations (manufacture, integration, O-Level, I-Level, D-Level) and support required at all locations will be determined.

d. Methods for specification, procurement and acceptance of advanced Avionics Readiness capability will be developed. In this regard, quantitative values and their measurement techniques for all readiness and readiness related parameters will be developed. These values will be suitable for use in development, procurement specifications and evaluation. Warranty programs will be evaluated. Criteria for demonstration of Avionic Readiness will be developed. Modification of DSARC rules as they apply to Avionics Readiness will be recommended.

e. Cost factors, measurements and methods for all elements of Avionics Readiness as applied to advanced technologies will be developed. Program cost methodologies such as Design to Cost or Life Cycle Cost techniques will be developed and/or refined as engineering tools and as visibility aids to system and program management.

A special objective of this program will be the determination of skills and training required by fleet personnel to perform the required test and maintenance actions at each level of maintenance. Every attempt will be made to require avionics end item design features that simplify the test and maintenance requirements and supporting documentation.

This program will determine the level and effectiveness of test and maintenance that is practical for inclusion in each avionics application. Weight, volume, power, control and mission essential functions will be subjects of the analysis.

Every attempt will be made in the program to keep its objectives practical and oriented toward human capabilities and problems. Treatment of ATE or software as a panecea or the human as subservient to the computer will be avoided. The program will make recommendations consistent with the operational requirements and doctrine of the fleet.

1.3 Scope of the Effort - The areas identified in paragraph 1.1 have been key elements around which to structure a program. By the same token, they have opened up many other related areas such as cost, specifications, procurement, acquisition, levels of support, data collection and feedback, etc., that must be addressed as either part of this program or related programs if across the board impact on future Avionics Readiness is to be achieved.

The effort expended to date, therefore, has been to briefly and broadly review the many on-going efforts considered applicable and/or associated with the Avionics Readiness Program. Initially, it may appear that this program is just one more approach to the problem. It is, in fact, much greater in scope and encompasses all the other efforts. One should remember that the task of this plan is long term, looking beyond the immediate short term problems of today which many of the on-going efforts are addressing. This plan will build on today's efforts but not become part of them.

The result then, has been to structure the Plan into two volumes. Volume I addresses the many issues faced today and the goals, options, approaches and potential applications of development efforts which are envisioned at this time as the methods necessary to achieve success for the future.

Volume II is an implementation plan which will prioritize and specify work tasks, levels of funding, detailed schedules, deliverables and the manpower and material necessary to support the effort.

The Program is structured around five major work areas: Technology Assessment, Technology Applications, System Applications, Specifications and Procurement, and Cost. It provides for in-depth study, analysis, development, planning and documentation in all areas.

Section 1 deals with general issues. Section 2 deals with planning and project management. Appendix A is a specific example of the detailed work task planning which will be contained in Volume II. Appendices B through F deal with each major work area in detail. In each appendix, the subject is discussed by definition and issue. Recommended tasks are included and are interrelated. All tasks will be coordinated in the Implementation Plan.

1.4 Background - Considerable changes in the maintenance of avionics weapons systems have occurred since the growth of the Navy carrier forces in World War II. Steady progress has ensued from the early pieces of individual, manually operated test equipments to Special Support Equipment for individual weapon systems, to highly automated and complex Special and Automatic Test Equipment of today. The need for this progress, of course, is the increasing complexity of the avionics weapons suits. The Navy, as well as other military forces, are caught in a weapons technology spiral that demands the earliest introduction of improved capability and performance that technology can provide. The problems associated with maintaining avionics systems in an operationally ready condition are becoming increasingly more difficult to solve.

Recognition of the growing problem prompted the Navy to initiate the VAST (Versatile Avionics Shop Tester) program about ten years ago. The VAST concept was to consolidate programmable test equipment under the control of a central processor into a single, modular test station. The VAST could be programmed to test a wide variety of avionics hardware, conserve shop space aboard aircraft carriers, and reduce the requirements for highly skilled personnel to maintain and repair avionics hardware.

The VAST concept as originally conceived is a very viable approach. However, since the introduction of VAST stations into the fleet approximately five years ago, problems have been encountered which were not originally envisioned. Efforts are underway to correct deficiencies to the VAST which have been identified. Other deficiencies, however, can be attributed to the interface between the VAST and the UUT (Unit Under Test), either because of the interpretation of the specifications or the design of the basic avionics equipments. The solution to this problem has been the design, development and procurement of complex ID (Interface Devices) and corresponding software routines to attain the desired compatibility. Correspondingly, the skill level of maintenance personnel must increase in order to comprehend the VAST, ID and UUT. Additional shop space is required to store the ID's and program test routines.

To supplement the VAST, the Navy has recently approved the development and procurement of HATS (Hybrid Automatic Test Set). HATS was required to support selected S-3A SRA's (Shop Replaceable Assemblies) which could not be tested on VAST. HATS is a third generation test set, (the designation of testers with Programmable Interface Unit), which will be capable of providing maintenance support for a wide variety of equipments. The major concern is that although the cost of the basic test set is relatively low (approximately $500K/unit), the cost of the software design and development is high (approximately $50K/SRA).

The accelerating cost of maintenance and support systems has attracted the attention of CNM and COMNAVAIRSYSCOM, and is the factor which has given impetus to the Avionics Readiness Program. Future avionics systems promise to be more complex with corresponding increased costs to achieve and maintain an effective level of readiness.

This program presents a plan to reverse the trend by identifying the major issues contributing to the problem based on the experiences gained on past and present day systems, and by implementing development programs founded on advanced technologies.

1.5 Broad Issues - Intuitively, it is felt that future avionic devices and systems must have a dramatically improved "self contained" test and maintenance capability in order to simplify the support system requirement. The extent to which test and maintenance features can practically be incorporated into the avionics function has not been determined and represents a critical uncertainty in readiness and support planning for future systems. If however, suitable support is to be obtained, priorities in the development of avionic systems need to change and include Life Cycle Cost and support objectives as well as performance and operational objectives. Such reordering of priorities will be extremely difficult to achieve in practical application. Nevertheless, it is achievable providing certain issues are dealt with and resolved.

A list of issues pertinent to future Avionics Readiness is presented here in question form. Each is discussed in greater detail in the body of the plan. Electronics-X addresses similar issues, but in considerably more detail. This program concurs with Electronics-X on the basic issues and with many of its findings, and addresses specific programs and efforts for the resolution of these issues.

a. Goals - For any given weapon system or systems, how are meaningful Life Cycle Cost/Design to Cost/Support Goals established? What cost, support and performance boundaries are imposed on the systems designer?

b. Costs - How can Design to Cost/Life Cycle Cost/Cost Effectiveness techniques be made accurate and applied to the avionic development

phases as a design tool? How can these cost methods be used as an accurate management visibility tool? How are costs controlled and performance and readiness objectives still met?

c. Schedule - Where in the avionics evolution should the maintenance and support systems be developed in order to be evaluated for service approval and be fully implemented at IOC?

d. Evaluation - How do we specify, measure, demonstrate, and evaluate support features in avionics prior to commitment to buy production quantities?

e. Engineering Application - What are the most cost effective trades to be made in avionic systems between performance and supportability? How are these tradeoffs made?

f. Technology Impacts - What opportunities and characteristics exist in the advanced technologies that can be exploited for a Readiness/Support objective? When will these technologies be available? What future weapon systems are candidates for advanced technology application? To what degree can the new avionics technologies eliminate or reduce the maintenance and support need at all maintenance levels?

g. ATE Projection - What new requirements in stimulus and measurement will be necessitated by advanced avionics systems? To what degree should major ATE (Automatic Test Equipment) or HATS (Hybrid Automatic Test System) constrain the application of advanced technology?

h. Programs - What program(s) are underway in DOD and the U.S. Navy to resolve these issues? To what degree have they been coordinated? Do they have common objectives?

At best, there are only partial answers to the above issues. The exact interrelationships between these issues and the methods required to simultaneously resolve them to a position of advantage, is presently not known. All these issues must be addressed simultaneously and without bias. None of these issues should be treated as wholly separate, as they all interact. These issues and others will be addressed by the Avionics Readiness Program and will be the subject of exploratory development efforts described in this plan.

1.6 Approach

Planning Approach - The research conducted in the preparation of this plan indicated a broad level of effort already underway on many of the issues addressed in this plan. A comprehensive assessment of the ongoing effort was considered too large an undertaking for the initial three months allocated for plan preparation. Not wishing to propose work that would be in conflict or redundant with these efforts, the plan was divided into two volumes, each deliverable at different dates. The division in time between Volume I and Volume II allowed for a concentration of effort on general planning as opposed to the detailed planning of implementation.

Volume I is the general plan and deals with issues, approaches, goals, objectives, overall schedules, applications, and recommended work task areas. Volume II contains specific work task description, levels of funding, detailed schedules, description of deliverables, recommendation for priority of work, and manpower and material requirements. Volume II also makes recommendations concerning in-house/contractor workload distribution. It was deemed prudent that approval of the general plan should be obtained before commencing the detailed planning for Volume II. Volume II will be delivered no later than 90 days after approval of the general plan, Volume I.

Technical Approach - The technical approach recommended by this plan is one of Systems Design. All elements related to the Readiness and support objective will be treated simultaneously, equally, and as interrelated elements with the objective of establishing cost effective tradeoffs. Figure 1.1 represents the major discipline areas in support planning, design, and procurement that are directly or indirectly controlled by the design of the avionics end item. Figure 1.2 represents the work sequence in which each area of figure 1.1 will be investigated.

The initial efforts will be in Technology Assessment. During this phase, the characteristics, failure, test and repair modes of each of advanced technology components and devices will be applied to each of the six discipline areas of figure 1.1. During the Technology Application phase, each of the advanced technologies, as they may be implemented at a subsystem level, will be applied to the areas in figure 1.1. The third phase, System Application, will again exercise each area, but at the whole weapon system level. The program will result in methods, measures, evaluation criteria, recommendations, standards and specifications for obtaining cost effective avionics support. When, however, specific issues or points must be demonstrated, actual design and fabrication of hardware and/or software functions will be undertaken to resolve the issue. Each phase of this program will be fully and independently documented.

The Specification and Procurement phase summarizes and applies the result of all previous work, and develops specifications, demonstration, evaluation and acceptance criteria in support of actual weapon systems procurement.

All efforts shown in figure 1.2 are continuously evaluated with respect to cost. Life Cycle Cost and Design To Cost models will be employed.

This program is intended to dovetail directly into live weapon system development and acquisition.

1.7 Planning Factors - The development of the Avionics Readiness Program Plan requires the integration of many factors, including scope of effort, objectives, opportunities, impact, schedules, funding, priorities,work activity by Navy labs, other services, and industry. These are discussed in the following paragraphs. The latter four subjects are treated in detail in Volume II.

a. Plan Objective - The objective of this plan is to establish an integrated development structure wherein all pertinent elements of Avionics design and support systems design can be evaluated with respect to each other and with respect to new technologies and requirements. In this manner the support of future Avionic Systems may be predetermined and cost effective.

b. Utilization of Resources - High level skills exist throughout the nation in all avionic design, support design and cost disciplines. Although the primary intent of the plan is to identify work activity to be accomplished by the NAVAIRDEVCEN and other Navy labs, it can also serve as an architecture for organized development of Avionics Readiness capability at the national level of government and industry.

c. Scope - Scope of effort is broad, dealing with all future Navy aircraft and all elements and disciplines that effect Avionics Readiness. The plan, therefore, approaches the development in the general sense. This approach demands a somewhat slow and conservative process. If it is to have broad effect, the risk factor must be kept low. The plan will concern itself with the design, manufacturing, integration, acquisition and support phases of avionic systems and subsystems to the extent that each of these phases may impact Avionics Readiness.

d. Risk - The risk of introducing Avionic Readiness (approaches, techniques and requirements, developed as a result of this plan) is primarily a function of how well the improved readiness capability can be demonstrated. Funding limitations may dictate a limited scope demonstration of improvement; therefore, extreme care will be used in the selection of technologies and issues to be demonstrated. Risk at time of fleet introduction will be substantially reduced if Avionics Readiness is developed and predemonstrated at an entire weapon system level. Additional risk is incurred if the program is too conservative and thereby too long in time, in that implemented recommendations may not correctly match technology. Care must be taken in scheduling and selecting target weapon systems for impact.

e. Impact - Impact of the Avionics Readiness Plan is directed toward the inclusion of test and maintenance features in the avionics end item to the extent that the need for complex support and test systems is eliminated or substantially reduced. It is anticipated that better success will be achieved in the low power digital areas than in high power, RF and analog areas. Nevertheless, these latter areas can also be bounded and improved. The theme that is prevalent throughout this plan is that simultaneous design of both avionics end item and all support elements is essential. The schedule of figure 1.3 has been arranged so that the requirements and results of the Avionics Readiness effort precede and/or overlap the Contract Definition Phase or EDM (Engineering Development Model) stage in the Weapon System evolution. Significant effort in the plan is devoted to the subject of Cost Effectiveness measures, Readiness measures, support measures and goals to the extent that the Avionics design and development community can make quantitative trades between performance and support requirements. In order to achieve impact in this area, time must be allotted to reorient avionic design engineers, managers and planners to test and support priorities and objectives.

f. Time Constraints - Figure 1.4 is a summary of the time and events shown in figure 1.3. The earliest this effort can be expected to have whole weapon system impact is approximately seven years from program start. Should maximum time spans be imposed in all areas, results would not be implemented in fleet weapons for eleven years. The latter time span is considered too remote and suffers the problems of credibility and possibility of a technology change in mid-program. Eight years is a reasonable impact target area for currently anticipated levels of funding.

g. Weapon System Schedules - The opportunity to apply the results of this plan to actual weapon systems is a function of scheduled new weapon system/avionic system introduction and the maturing of certain technologies and their application to the test and support objective. Technology thresholds and stability points will be defined where they exist. These points will be matched to both test and support capability and to system introduction schedules. The current NAP (Naval Aviation Plan) indicates a number of new weapons systems planned for introduction in the early 1980's. The next group of systems appears after 1986. In accordance with time constraints, it appears that an accelerated Avionics Readiness effort is required to meet the early group of weapon systems.

h. Funding - The exact levels and final distribution of funds directly available for application to this program are not known at this time. Volume II deals with specific funding requirements for the next two fiscal years and projected funding requirements for subsequent years. Funding for the first and second year will be directed primarily toward a manpower effort. Funding levels for the third and fourth years of this program will include equipment development and support demonstration.

i. Related Work - Recent investigation indicates that significant efforts in all subjects of this plan are underway by many activities in the military, industrial and university community. Care must be taken to exploit that which has been done and not re-invent the wheel. One of the values of this program may be its utility as a focal point of Avionics Readiness efforts.

j. Related Programs - There are several programs underway or planned for that have sympathetic objectives to the Avionics Readiness Program. AADC, BIACCS, and W21W1 Advanced ASW Systems are programs of this nature, having primary objectives directed toward performance and secondary or tertiary objectives toward readiness. Further examples include AIR 360/370 technology applications program, NELC's work in ATE, NAFI's development of "BITE" design guidelines, and NAEC's effort on AAFIS.

k. Detailed Avionics Readiness Program Schedules - Figure 1.5 is a systems cost effectiveness flow diagram. This diagram will be discussed in greater detail in section 4.1. Examination of the figure indicates that in order to achieve a cost effective system, simultaneous design of all performance and support elements must occur. The requirement for simultaneous design may not be implementable because of 6.3 and 6.4 funding category limitations. It is suggested here that the development process, and attendant funding structure as we know it, may be self frustrating toward the Readiness objective.

Figure 1.3 Avionics Readiness Program Schedule is a top level planning schedule that relates typical weapon system development time spans (upper third of diagram), Avionic Development time spans (middle third), and the Avionics Readiness Program (lower third). Examination of the figure reveals that a support system design and implementation

effort is required between DSARC II and DSARC III. These efforts are represented by the darkened areas. Development of support at the times indicated can result in tangible demonstration of actual test capability at time of service approval. It also assures that support capability is achieved prior to DSARC IIIA. Under current weapons systems planning, support capability always lags IOC.

A major factor in the development of this plan is the superimposition of the payoff period of the Avionics Readiness Program with the EDM/Contract Definition phases (DSARC II - DSARC III Period) of Avionics and Weapon Systems Development. Attempts to incorporate Avionics Readiness features after the EDM/CD are futile, as the inherent 10-20 year life time characteristics of the equipment for performance and maintenance have been established in the 12-18 month/ EDM/CD window. In any level of development (weapon system, subsystem or black box) the EDM/CD phase is the primary area of impact in determining the required levels of support.

GFE equipment developments that fall into the ADM/EDM cycle are structured across 6.2 - 6.4 category funds. Levels of funding are often barely adequate for the development of the avionics end item. Funds are not normally available in sufficient quantity to develop the "test and maintenance system" that supports the avionics. With the development of VAST, HATS and other automatic testing, the cost of fully developing the ATE, SSE, Interconnect Devices, Diagnostic programs, control documentation and Procedural manuals that comprise the support system often rivals the cost of the Avionics end item. Therefore, maintenance and test system development is put off until the larger monies of preproduction and production are available; by then the opportunity for cost effective design for support has been missed.

The Avionics Readiness Program attacks the EDM/CD phase directly and proposes to develop a test/maintenance capability that makes concurrent development of Readiness capability economically feasible and provides demonstratable output prior to service approval.

Figure 1.6, Avionics Readiness Task Area and Level of Effort Schedule, is an enlargement of the first five years of the Avionics Readiness Program. The program has five distinct phases.

a. Planning - An early concentrated effort to establish goals, scope, approaches and funding is shown. A level of planning will be maintained throughout the entire program. An assessment of Readiness Improvement activity at the national level will be conducted early and maintained throughout the life of the program.

b. Study and Design - During this phase, basic research is done in determining the nature and availability of the advanced technologies. Test and Repair requirements for these technologies will be developed at the component, SRA, WRA, and subsystem level. Where development of new test/repair devices and/or capability is required, experiments will be planned involving actual development of hardware and/or software as necessary. Design of the selected experiment will be conducted during this period.

c. Development - During this phase, the object of the experiment will be fabricated, tested and demonstrated. System tradeoff studies will commence. System approaches to avionics performance and Avionics Readiness tradeoffs will be developed. Cost analysis will be performed in support of all activity.

d. Implementation - System tradeoff will be completed during this period and new work started where deficiencies exist or new requirements

are manifest. Test and Repair specifications suitable for incorporation in procurement specifications will be developed. Cost methods, goals and Life Cycle/Design to Cost criteria will be established. Acceptance and assurance criteria for the prime avionics end item with regard to its Readiness characteristic will be developed. Test and Maintenance capability required in the avionics end item will be specified.

e. Payoff Period - During this period the results of the preceding four years of labor should begin to impact the acquisition of avionics and weapon systems. Activities conducted under the Program should cease except for support of ongoing procurements.

The Avionics Readiness Program should be renewed to keep pace with technology advances.

Relative levels of effort are presented in graphic form at the bottom of figure 1.6. Each of these efforts are related to a major effort of the plan and are time phased to the five year structure above. Inspection of these graphs indicates an initial Navy effort in technology assessment, followed by a buildup in technology application. Peak workload and program activity will occur in the third year of the program.

In figure 1.6 the levels of effort indicated apply only to the category in which they appear. No attempt should be made to relate the level of effort in one category to that of another.

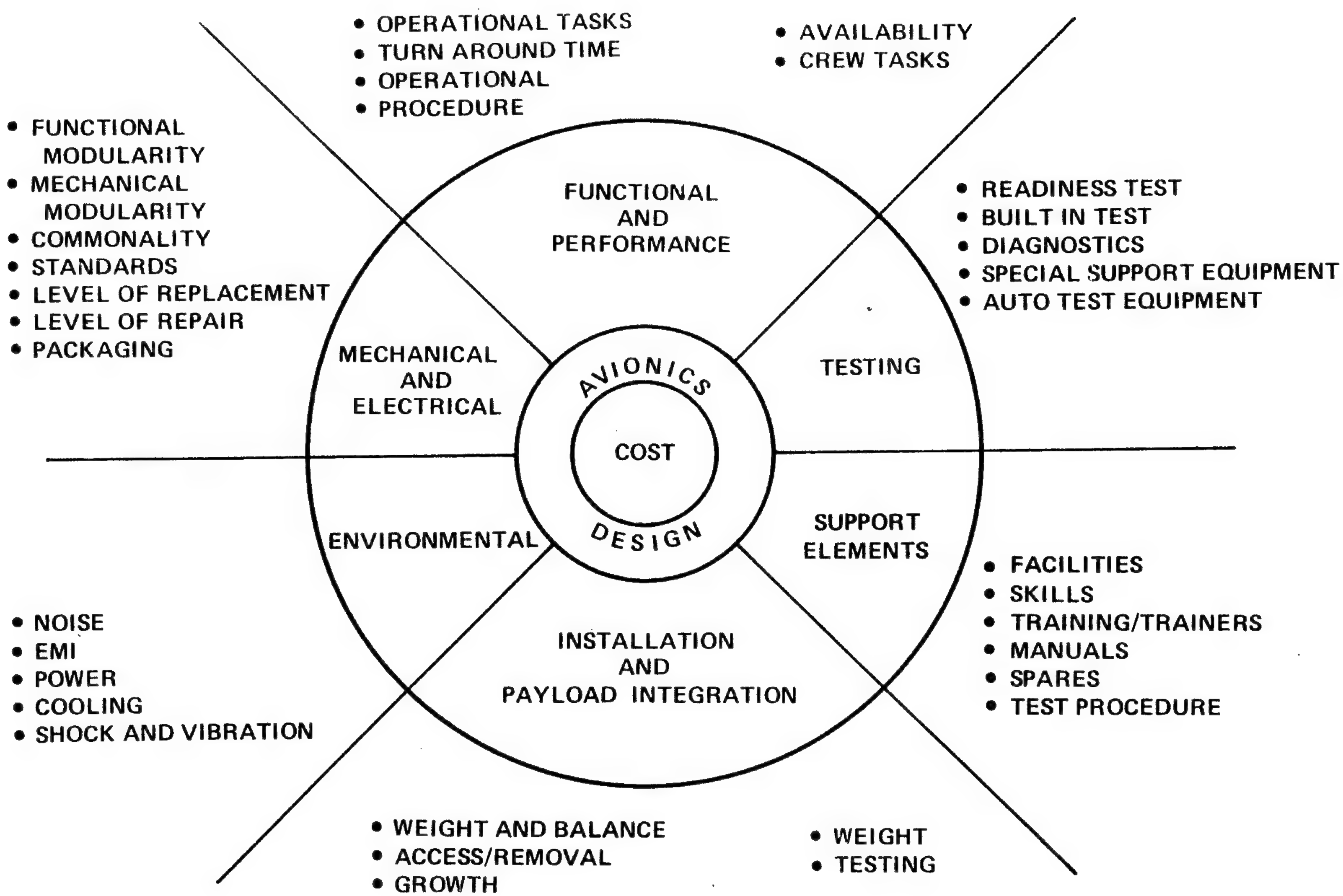

Figure 1.1 Systems Design for Avionics Readiness

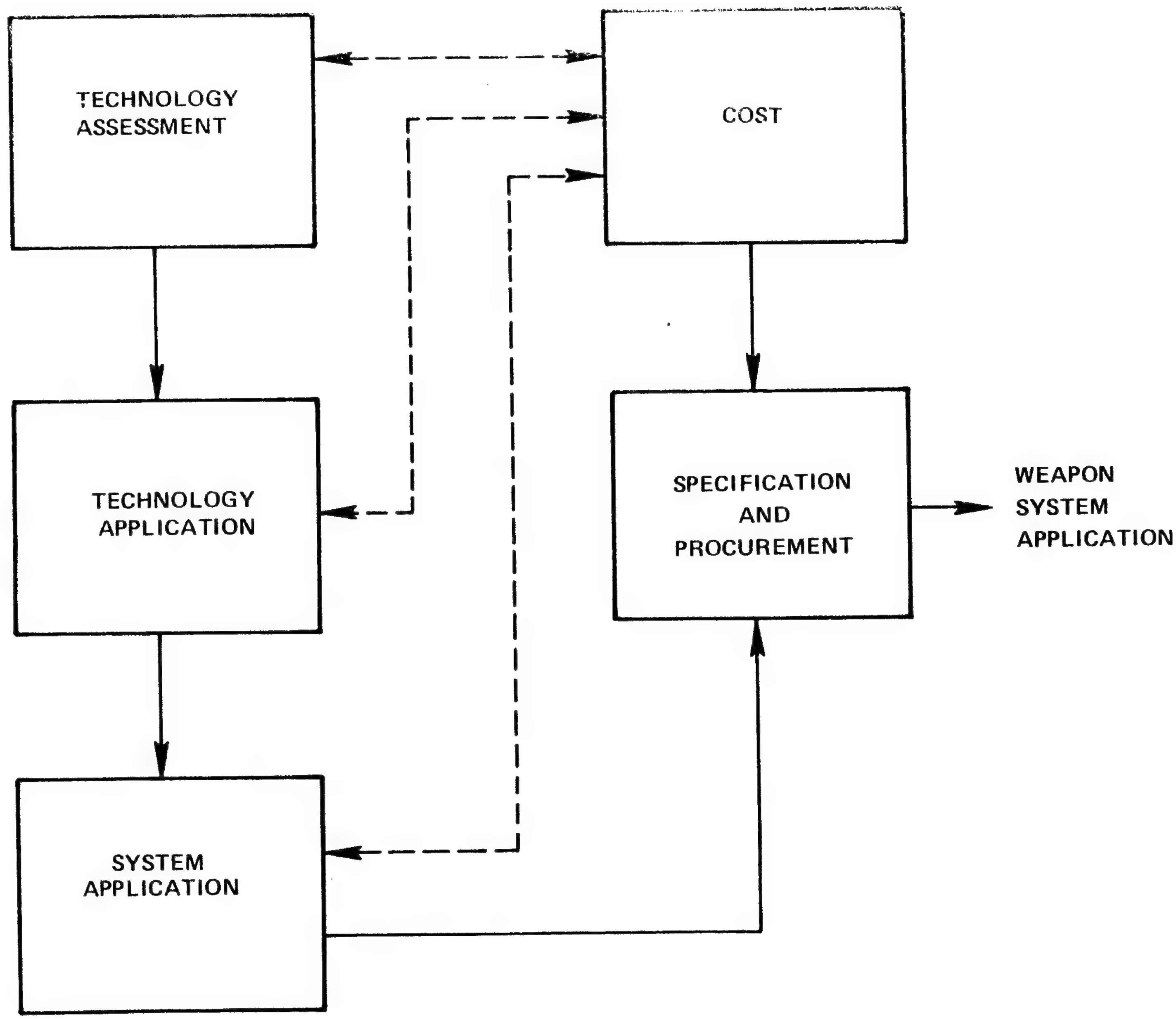

Fig. 1.2 Avionics Readiness Work Flow

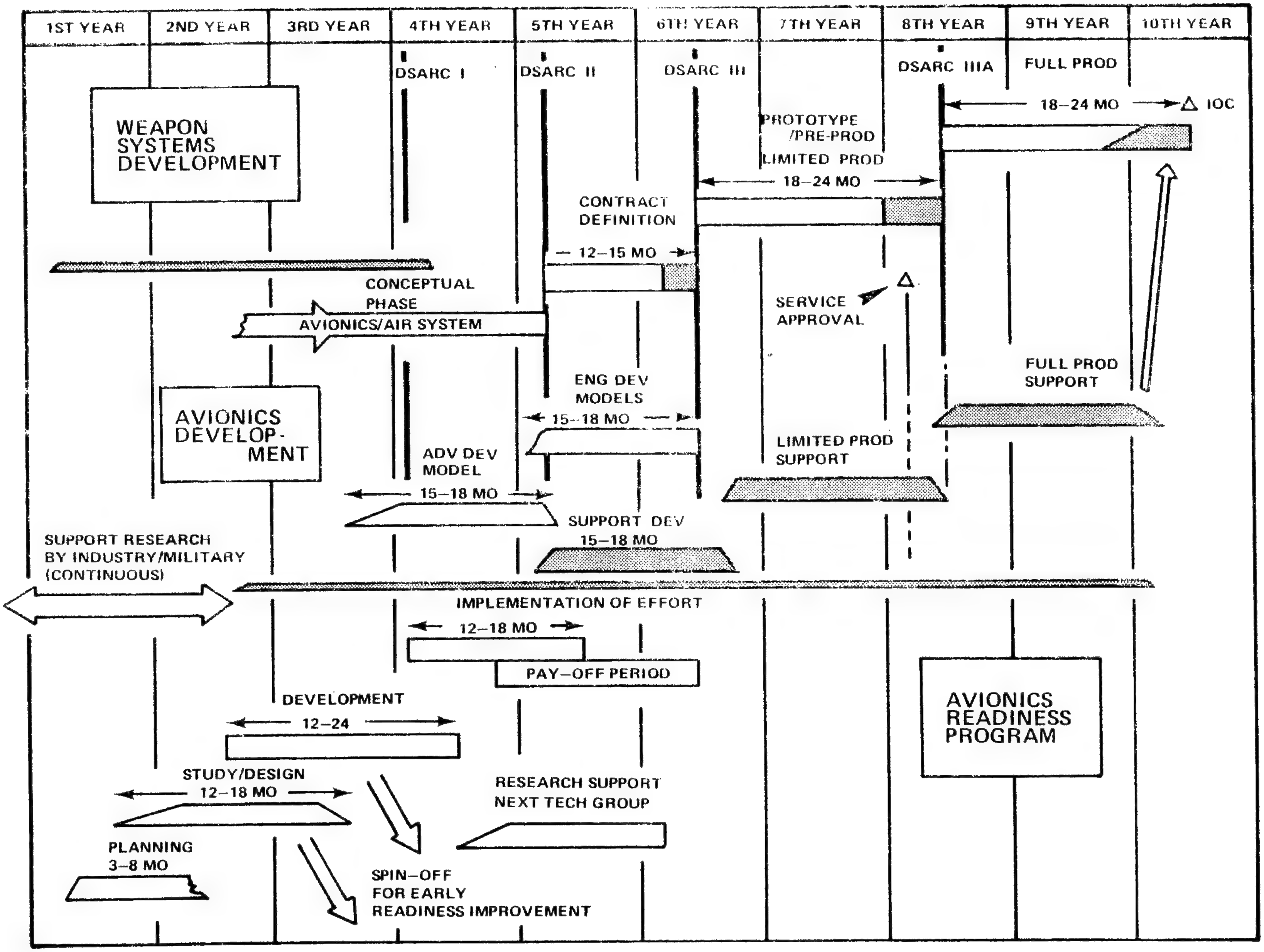

Fig. 1.3 Avionic Readiness Program — Schedule — 1st Weapon System Application

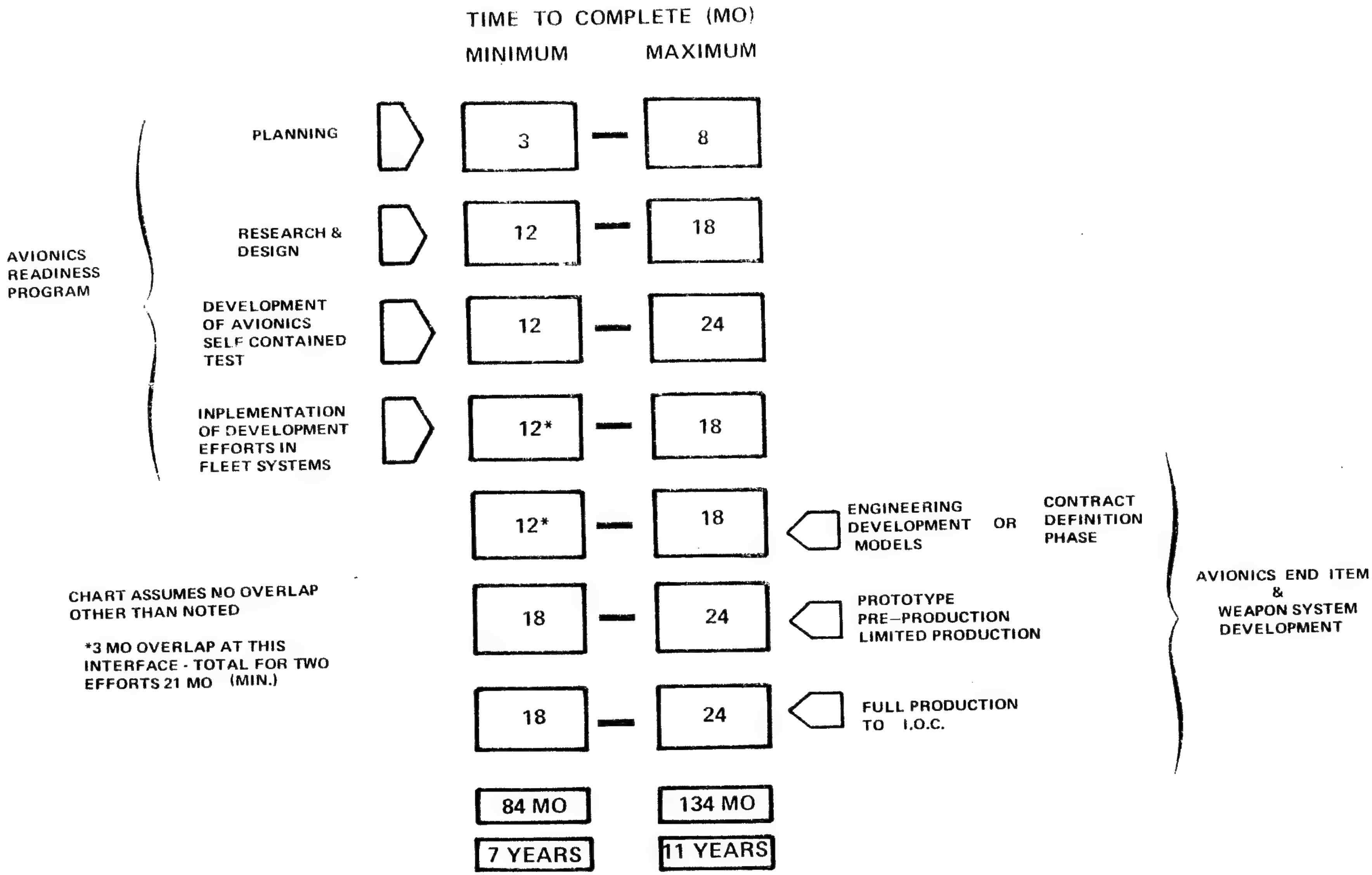

Fig. 1.4 Years to 1st Fleet Application of Avionics Readiness Program

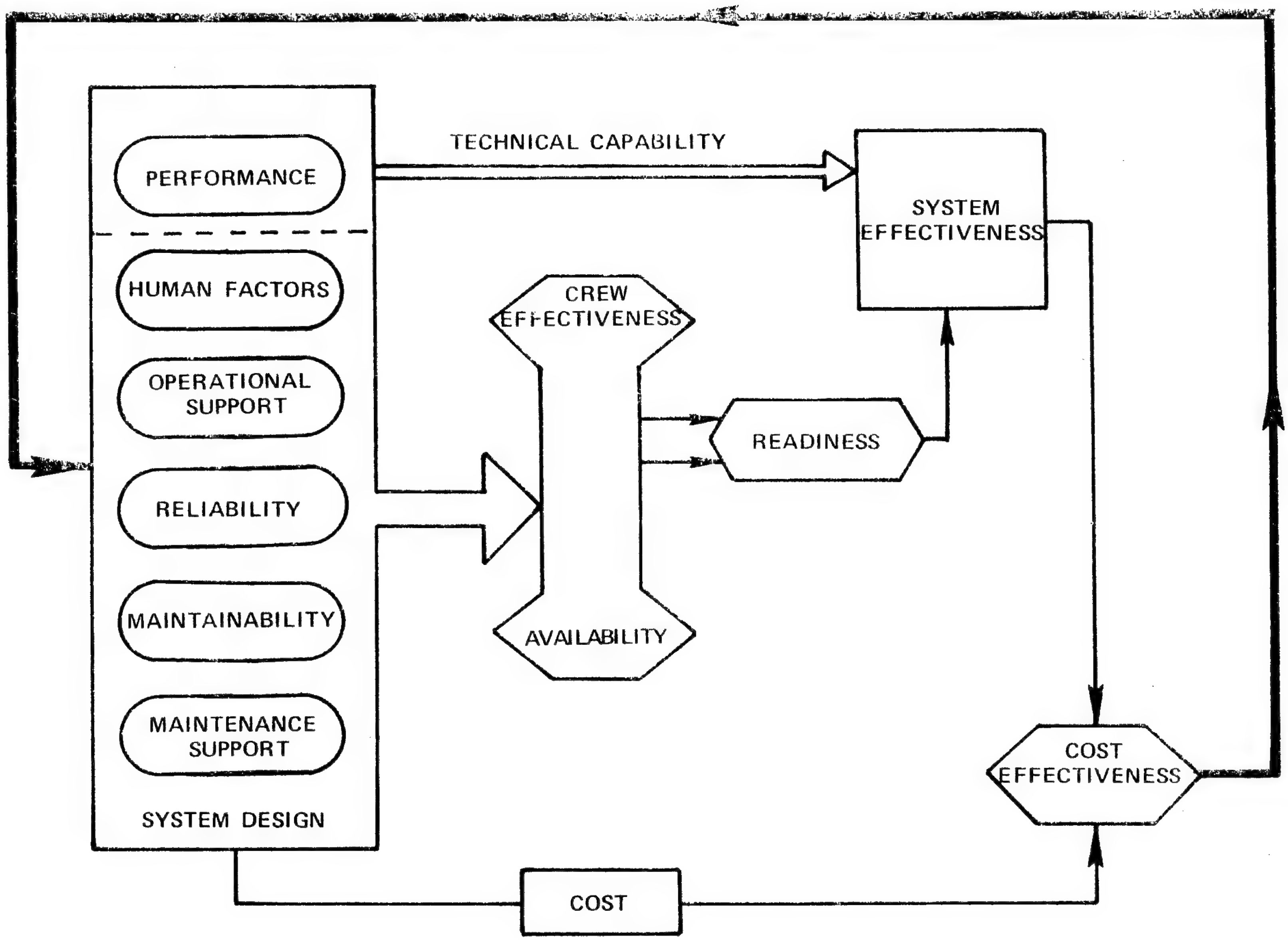

Fig. 1.5 System Cost Effectiveness Flow Diagram

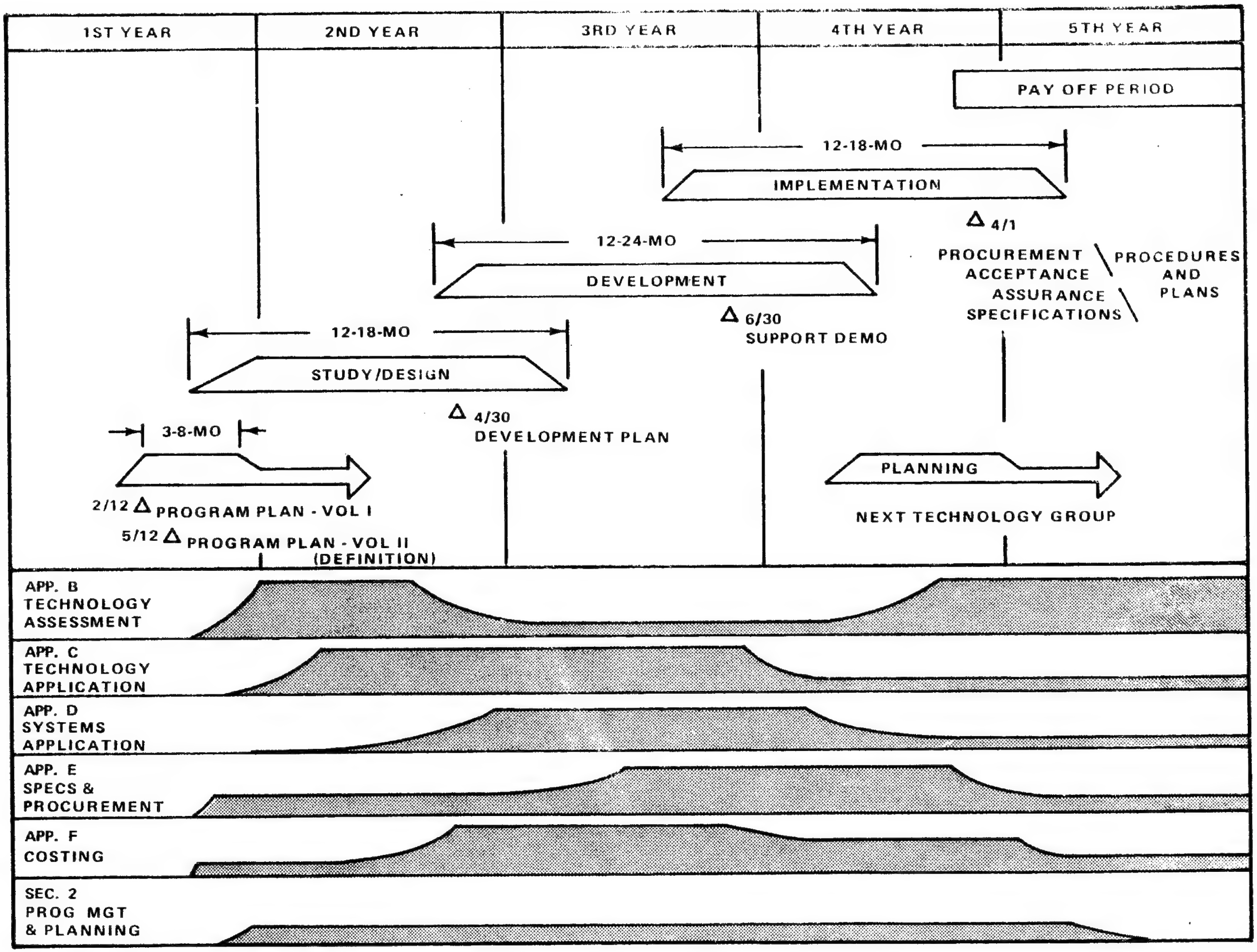

Fig. 1.6 Avionic Readiness Task Area and Level of Effort Schedule

SECTION II

PROJECT MANAGEMENT AND PLANNING

2.1 Program Assessment - In any program that has broad and ambitious objectives, there is the certainty that limited success will be achieved for a number of those objectives. For a variety of reasons, certain undertakings will not achieve the success envisioned. Funding limitations, lack of suitable technology, changing priorities, planning, changing requirements, etc., are just some of the causes for program failure.

To achieve maximum success, a continuous assessment of progress, opportunities and application must be made and programs modified where necessary. This section of the plan proposes to provide the continuing program review, anticipatory planning, and flexibility necessary to a successful program.

Sections 2.2 and 2.3 are companions to this section but with different orientations. Section 2.2 deals with opportunities and applications to future weapons systems and future avionics systems as contrasted to this section, which is concerned primarily with ongoing work.

Section 2.3 deals with the control and administration of the project. All three sections are functions of the Program Manager and form the basic structure for integral program control and planning.

A major function of this program is continual assessment of the elements that affect or will be affected by the end products of the program. In this regard, continuing assessment will be made of:

a. State of art of Avionics Readiness on a global basis, including all U.S. military forces and commercial air services, both domestic and international.

b. Fleet operating procedures, requirements, and limitations, including impact of the volunteer force, Squadron and maintenance

activity manning levels, effects of job program aids, skills distribution, etc.

c. The characteristics of support and logistic problem areas, including pipelines, ECP's and configuration control, repair of repairables, maintenance documentation, etc.

d. Avionics growth characteristics in terms of heat per unit volume, weight per unit volume, functional densities per unit volume, installation efficiency, cost per unit volume, etc., with an eye toward the aircraft ability to support the payload.

e. Cost trends of avionic support including parts cost, personnel cost, development costs, software costs and economic trends.

The above list represents suggested areas of importance to Avionics Readiness planning which need to be further developed. The results of the assessments across these broad areas would be used to project future Avionics Readiness trends and deficiencies, and to establish a baseline or reference point by which to evaluate efforts of the ongoing Avionics Readiness Program.

The Avionics Readiness Program in itself would be subject to a continual evaluation of goals, emphasis, progress, and potential payoff. Where necessary, recommendation would be made to NAVAIRSYSCOM to discontinue, accelerate, or redirect programs and efforts.

2.2 Future Systems Opportunities - The cohesive and driving force for the issues and tasks of the Avionics Readiness Program is the opportunity to apply the results of this program to future Navy Weapon Systems. These opportunities exist in both subsystems and major weapons systems planned for development in the 1975-1985 time frame and for procurement in the 1980-2000 time frame.

The NAP (Naval Aviation Plan) draft of August 1974 provides the basis for the issues under consideration and the Weapon System planning data necessary for determining the Avionics Readiness Program schedule and opportunities.*

The first goal of the NAP is Reliability and Maintainability. "R&M must be designed and built into all new weapons systems. It must be included in the aircraft subsystem components, the weapons and support equipment. Special emphasis is required on reliability and simplicity of operation of complex weaponry in a combat environment." This goal of the NAP is a primary issue. In order to achieve this goal, supportability must be given equal consideration with performance in instituting the design of avionics end items.

Electronics-X identifies the current DOD and industrial policies, procedures and practices in development production and operational support that most significantly influence the cost and reliability of military electronics. It recommends changes to reduce and control cost and to improve reliability.

The practical implementation of this plan is structured in two parts:

a. Development Efforts - The efforts identified in this plan will be developed through application of specific test and support methods and parameters to actual subsystem designs, such as the AADC (Advanced Avionics Digital Computer) or the BIACC (Basic Integrated Avionics Command Control). The AADC, BIACC and other NAVAIR 03 developments

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* The NAP is classified SECRET. To retain the unclassified posture of this volume, detailed aircraft procurement schedules have been omitted.

are being coordinated as described in the NAVAIRDEVCEN study, "Technology Systems Implementation Plan". These developments represent ongoing efforts which may support the Avionics Readiness Program. Other potential candidates suitable for Avionics Readiness design efforts include; electro-optic systems (ORADS/ORICS), ESM equipment, solid state radar systems and display systems (AIMIS).

The logical progression of this plan is to apply the methodologies and capabilities developed on the subsystem level to the development of a total and complete major weapons system. The major considerations for the weapons system selected as the potential candidate are:

(1) The planned IOC of the system is sufficiently advanced in time to allow the results of this program to sufficiently impact the development schedule.

(2) The system should be a generic representation of a weapons suit such as ASW, MTAC (Medium Tactical Aircraft), LTAC (Light Tactical Aircraft), etc.

(3) The system should exhibit the most promising potential for commonality across other weapons systems as examplified in table 1.

b. Production Application - Application of efforts to development and acquisition of specific weapons systems detailed in the NAP should be targeted for the early 1980's and subsequent years.

Potential production candidates for implementation of a total system design approach to Avionics Readiness include VFALX, VSTOL, VPX and VAMX. The NAP identifies these platforms as planned for acquisition in the 1980-2000 year period. Comparing the planned IOC of each platform and the common requirements shown in table 1

TABLE 1[2]

REQUIREMENT COMMONALITY MATRIX

Avionics Subsystems/ Product Lines	System Product Lines VP	VS	IIX	LAMPS	VAW	VA	VF
Acoustics - Active Sens.	R	R	R	R			
- Passive Sens.	R	R	R	R		(1)	
Radar - ASW	R	R	R	R			
- Surface	R	R	R	R		R	
- Air	PR				R		R
ESM/ECM	R	R	R	R	R	R	R
Electro-Optic - MAD	R	R	R	R			
- IR	R	R	R	R		R	PR
- TV/Photo	R	R	R	R		R	PR
- LASER	R	R	R	R		R	PR
Communication - ASW	R	R	R	R		(1)	
- TAW	PR			PR	R	R	R
- General	R	R	R	R	R	R	R
Navigation - General	R	R	R	R	R	R	R
- Sensor Ref.	R	R	R	R			
Signal/Data Processing	R	R	R	R	R	R	R
Displays/Controls	R	R	R	R	R	R	R
Recording	R	R	R	R	R	R	R
Automatic Flight Control	(2)	(2)	(2)	(2)	(2)	R	R

R = Requirements exist.

PR = Possible requirements exist for specific platform. Definite requirements exist for some similar generic platforms.

(1) = VA have been used as auxiliary sonobuoy plant and RF relay vehicles through use of pods.

(2) = May be desirable to relieve boredom and allow pilots and copilots to perform longer missions.

2 Technology Systems Implementation Plan, NADC Study, Jan 1975.

indicates the potential impact which could result from the efforts proposed in this plan.

Work performed in accordance with this section would include:

(1) Continuous review and assessment of current and projected Navy weapons systems programs, with the objective of determining earliest opportunities and dates the Avionics Readiness Program could have full or partial impact.

(2) Determination of future weapons systems operational requirements and characteristics with the objective of keeping the goals and objectives of the Avionics Readiness Program current.

It is intended that the follow-on planning effort (Volume II) will be directed toward a detailed review of these subsystems to determine present design approach and constraints, the level of effort necessary to successfully apply the methodologies developed with time and budget constraints of this program and to select the appropriate candidates for implementation.

2.3 Avionics Readiness Project Management - Avionics Readiness project efforts at NAVAIRDEVCEN shall be performed in accordance with the project organization shown in figure 2.1. The Avionics Readiness task is assigned to the Director, Systems Analysis and Engineering Department (SAED, Code 50). He in turn assigns the task to the Chief Systems Engineer and to the Program Manager, Avionics Readiness.

The Program Manager, as staff to the Director, SAED, is responsible for establishing project requirements, priorities, planning, schedules, budget, progress assessment, preparing summary reports, conducting program reviews and generally protecting the interests of the Airtask and sponsor.

The Program Manager is the designated Principle Investigator on the Airtask and reports to the Director on program progress and status. The Program Manager has authority and requirement to establish direct liaison with the Washington sponsor. In this regard, the Program Manager will advise the sponsor on progress, problems and issues on an informal basis. All formal reports and correspondence will be channeled through the command. The Program Manager will provide planning and technical services to the Washington sponsor on a limited basis. The Program Manager negotiates directly with the Chief Engineer and/or Project Engineer in matters pertaining to schedules, budget, manpower and project implementation. The Program Manager can call upon the Chief Analyst and Chief Planner in SAED or the other departments on Center to assist in planning and staffing.

The Chief Engineer has line authority over various technical groups and functions within SAED. He is directly responsible for completing the engineering work described in the Airtask. The Chief Engineer or the Project Engineer, as convenient, will be the designated Associate Investigator on the Airtask. The Chief Engineer is responsible for Systems Design; planning relative to that design; project staffing; generation of detailed design specifications; design, development and fabrication of equipment; design, development and generation of software; integration, test, and demonstration of product; cost planning and status reporting.

The Project Engineer performs the duties of the Chief Engineer on specific Airtask efforts and on a continuous basis for the duration of the Airtask. Additionally, the Project Engineer is responsible for providing day to day direction to the main body of the engineering work force.

Project staffing will be drawn from the functional engineering divisions in SAED (hardware, software, ILS, etc.). These divisions

are not shown on the diagram. Where personnel from other departments are required to staff the work effort, their services will be obtained via an IDWA (Inter-Departmental Work Agreement).

Personnel assigned to the project will be organized into project groups suitable for accomplishing the work of the Airtask and Program Plan. For the Avionics Readiness Program the following project groups are established:

a. Technology Assessment and Application Group - Responsible for implementing appendices B and C.

b. System Application Group - Responsible for implementing appendix D.

c. Specifications and Procurement Group - Responsible for implementing appendix E.

d. Analysis and Costing Group - Responsible for implementing appendix F.

e. Section 2 of this plan will be jointly implemented by the Program Manager and the Project Engineer, with the primary responsibility being assigned to the Program Manager.

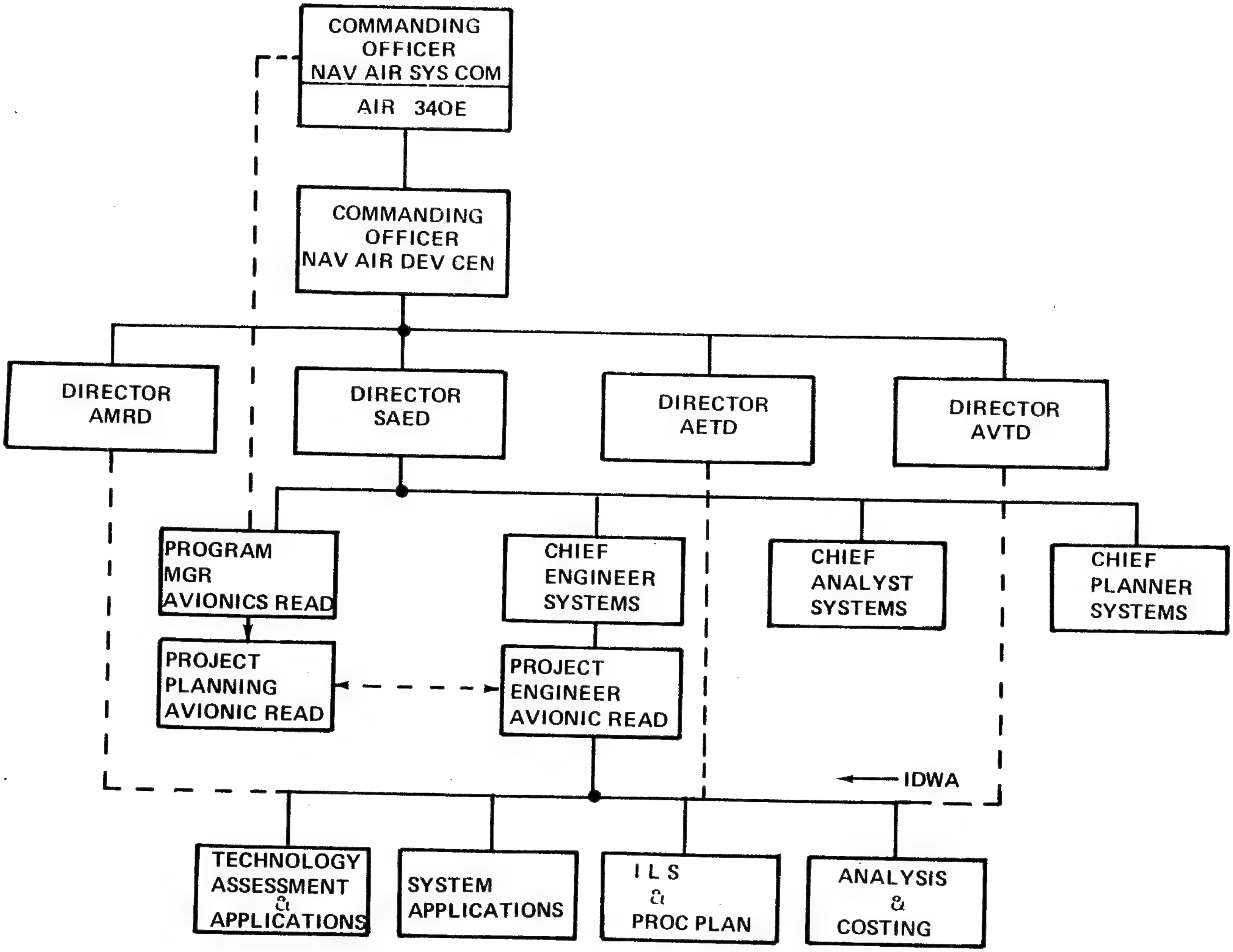

Fig. 2.1 - Avionics Readiness Project Organization

APPENDIX A

SAMPLE TASK PLAN

CONTENTS

1.0 Introduction - Appendix A contains an example of a typical Task Plan that will be submitted as part of the Avionics Readiness Program; Implementation Plan, Volume II.

Volume II will contain a Task Plan for each agreed upon element of work contained in Volume I or for other work efforts as required. Each Task Plan will be self contained but interfaced with other task plans where necessary.

Volume II will, in essence, be the master plan for the Avionics Readiness effort. It will contain milestones, schedules, tasks and funding requirements in summary from as well as individually in each Task Plan.

2.0 Discussion - Each Task Plan will be suitable for inclusion in the standard Airtask, either individually or in combination with other plans. The intent of the plan is to provide a disclosure of the Avionics Readiness Program effort in greater detail than one would find in the Airtask. Presumably, a single Airtask containing the equivalent planning data of several Task Plans would be voluminous. By simple reference to the Task Plan and inclusion of summary data from the plan, the Airtask can be kept reasonably small.

An additional objective of the Task Plan is to serve as an informal, living and working, planning document. As such, changes in scope, negotiation of effort and changes in plan implementation can occur without effecting the basic structure of the Airtask.

Each Task Plan will be organized into three parts: Management and Airtask Data, Work Task Descriptions and Schedules, and Detailed Planning Work Sheets. By thus dividing each plan, selected sections can be distributed to a wide variety of interested activities both within the government and within industry without revealing sensitive fiscal data or data of no interest to the reader.

Task Areas contained in each Appendix Section of Volume I are extremely general and are not intended as planning data. Their principle intent is to indicate the broad areas of work that must be accomplished in order to resolve the issues raised in the section texts. As such, they form the basis for discussion which will lead to solid planning decisions.

The Test Plan structure should support coordinated Avionics Readiness Activity through the Navy lab structure and industry, in that the "Task description and schedules" section can serve as vehicle for Airtask or Contract.

In order to assure coordinated effort between all Task Plans, Volume II will contain a Work Breakdown Structure which will relate each effort. The Task Plan has no standing or authority in itself, it is simply an informal working vehicle to resolve planning and task issues and to document agreed upon objectives, levels of effort, funding, schedules and other program information. The contents of the Task Plan will be in force only to the extent indicated in Airtask or Contract.

3.0 Task Format - Outline of the recommended format for an Avionics Readiness Program:

Task Plan:

I. Cover Sheets

A. Program Name
B. Task Plan Title
C. Task Plan Number
D. Preparing Activity
E. Preparing Individual(s)
F. Classification of Plan

II. Section I, Management & Airtask Data

A. Governing Airtask or Contract No.

B. NAVAIRSYSCOM Activity

C. Task Title

D. Task Number

E. Work Classification

F. Funding Category

G. Funding Requirement by Fiscal Year,
   Not to Exceed 5 years

H. Field Activity

   1. Name
   2. Principle Investigator
      Code, Name & Phone
   3. Associate Investigator
      Code, Name & Phone

I. Summary
   Description of Work

J. Major Contracts

   1. Contract Objective
   2. Contractor
   3. Contract Value

K. [illegible] [illegible]

III. Section II, Task Description

A. Task Title & Number

B. Specific Objectives

C. Work Statements

   1. Tasks
   2. Approach
   3. Limits and Constraints
   4. Required Support
   5. Interfaces

D. Milestones
E. Task Schedules
F. Related Efforts
G. Deliverables
H. Follow On Work

IV. Section IV, Planning Details

A. Task Plan Title & No.
B. Manpower/Material Schedules
C. Cost Work Sheets
D. Cost Summary Sheets

4.0 Sample Task Plan

UNCLASSIFIED

AVIONICS READINESS

DEVELOPMENT OF SUPPORT
SYSTEMS APPLICATION
MATRIX

TASK PLAN 400-30

Prepared By: U.S. NAVAL AIR DEVELOPMENT CENTER

Mr. J. X. Cobb
Mr. X. J. Smith

UNCLASSIFIED

CAUTION!!!

THIS TASK PLAN IS PRESENTED AS AN EXAMPLE ONLY AND HAS NO FACTUAL BASIS FOR DETAILED TASKS, SCHEDULES, OR FUNDS.

I. Avionics Readiness Program Management and Task Data

A. Airtask No. XXXXXXXXX

B. NAVAIRSYSCOM Activity: Air XXXX

C. Task Title: Tactical Display System, AN/ASA-(XX) Common Support Mode Development

D. Task No. 400-30

E. Task Classification: Unclassified

F. Funding Category: 6.2

G. Funding Requirement:

FY-75	FY-76	FY-76A	FY-77	FY-78
	230K	40K	60K	

H. Field Activity: U.S. Naval Air Development Center

Principle Investigator: Mr. J. X. Cobb, X4775/4776
Associate Investigator: Mr. X. J. Smith, X4771

I. Summary: The Tactical Display System AN/ASA-(XX) shall be analyzed for Readiness and Support features as defined in Avionics Readiness Program Report XXXX; for Organizational, Intermediate, Depot, and factory level testing techniques and support commonality. A single set of standard test requirements and data will be generated which will be used to develop test programs for each level of testing specified.

The equipment shall be modified, as necessary, to include the test features, BIT, testability, compatibility and uniformity of test to demonstrate the Avionics Readiness techniques described in Report #XXXY.

Cost elements generated as a result of the hardware/software redesign shall be used to develop a DTC/LCC model, which in turn will be used in the development of a cost/effectiveness number for the Display system.

The Task shall result in the demonstration of common support and test modes suitable for use at all levels of mainteance. Demonstration will contain a competitively procured TPS (Test Program Set).

J. Major Contracts

1. Easy View Jackson MFG Co: $85,000.00 (sole source)

Modification Kits for AN/ASA-(XX) Display

Manufacturer shall develop modification designs in accordance with NADC Equipment Specification (XXXXX). The manufacturers shall modify the appropriate modules and assemblies to implement the design and shall deliver these modifications to NADC in the form of a modification kit. TPS Interconnect Devices shall be included with the modification kit. As part of the deliverable documentation the manufacturer shall provide a detailed diagnostic test flow diagram of the display system.

2. Contractor (TBD) $75,000.00 (competitive)

Leading Candidates:
- BIT Flow Inc.
- Diagnostics Design Inc.
- Test System Co.
- West Coast Aero Space Inc.
- Long Island Aero Space Inc.

The contractor will provide programs and procedures in accordance with NADC specification (XXYY). Contractor shall assist in final test, debug and verification phase.

II. Task Description

A. Task Title: Tactical Display System Common Support Mode Development

Task No. 400-30

B. Objectives:

1. To demonstrate that common test design and common source documentation are suitable for generation of Test Programs and Documentation for several levels of maintenance, each of which has different test objectives and applications.

2. To demonstrate that Test Program Sets can be satisfactorily developed from competitive sources.

3. To demonstrate improved test capability by inclusion of document test features and circuits included, in the hardware, where these features have been selected to support specific software tests.

4. To develop the cost factors associated with test design and implementation for modeling and cost effectiveness comparisons to unmodified displays.

C. Work Statement

1. Task:

a. Develop Hardware Test Specs.

b. Develop TPS spec.

c. Procure Hardware modes, programs and documentation.

d. Set up and conduct demonstration.

e. Act as technical integrator for all hardware, software, test and demonstration efforts.

2. Approach

The Avionics Readiness development team shall analyze the TACTICAL DISPLAY SYSTEM and evaluate appropriate documentation for format and content, test requirement, uniformity of test at each test level, redundant data and compare this against the requirements of Avionics Readiness Report (XX) and (XX). A technical review of the system based on these reports shall include:

a. Functional commonality analysis

b. Circuit commonality and standardization

c. BITE circuitry

d. Testability

e. ATE compatibility

f. Hardware interface standardization commonality at the WRA and SRA interfaces

g. Software commonality

Where differences are revealed during the technical review, circuit designs shall be required and hardware developed to eliminate these differences, thus advancing the hardware to the desired test capability. The redesigned equipment shall be analyzed to provide the desired test data base, from which all tests programs shall be developed for each test level.

Redesigned equipment shall be bench tested to verify compliance with equipment performance specifications and the Avionics Readiness Report (XX).

Final demonstration of equipment and procedures will be accomplished in actual test environments. At the conclusion of the demonstration Navy specifications and procurement specifications shall be updated for future TPS.

Figure 1 is a flow diagram of tasks necessary to develop common test and support modes.

3. Limits and Constraints

Modification of the Display System must be such that form, fit and function are maintained, except for the test improvements.

4. Required Support

a. This task assumes funding for the development of modifications and TPS's only.

b. Equipment and facilities to be supplied at no direct cost to this task include:

(1) One each TACTICAL DISPLAY SYSTEM suitable for modification for a period not to exceed 18 months. TACTICAL DISPLAY SYSTEM will be refurbished to original condition and returned at task termination.

(2) VAST and/or Hats test facilities and stations as necessary for the final demonstration and program preparation

prior to demonstration. Work spaces required at West Coast Aircraft manufacturer's facility.

5. Interfaces

The Tactical Display system interface to the Aircraft tactical computer at the Organization Activity; the VAST and Hats test stations at the intermediate level facility.

D. Milestones

1.	Completion of Hardware modification and Test spec NADC spec (XXXX)	9/75
2.	Completion of TPS spec NADC spec (XXXX)	10/76
3.	Contract for Display Modification	1/76
4.	Solicit BIT's from inactivity for TPS Development	11/76
5.	Award TPS Development contract	4/76
6.	Receive MOD Kit	7/76
7.	Commence demonstration	2/77

E. Task Schedule

1.	Develop Test Design Spec	7/75 - 10/75
2.	Develop ownership cost profile for unmodified Tactical Display System	8/75 - 11/75
3.	Prepare Demonstration Plan	9/75 - 4/76
4.	Collect cost and usage data on unmodified Tactical Display System	12/75 - 12/76

5. Prepare Lab Integration Facility — 1/76 - 6/76

6. Run cost effectiveness trades and cost model — 4/76 - 2/77

7. Receive/accept/integrate display system and modification — 6/76 - 11/76

8. Prepare demonstration site (at aircraft manufacturing facility) — 8/76 - 11/76

9. Final integration — 11/76 - 3/77

10. Demonstration — 2/77 - 4/77

F. Related Efforts

1. Development of application of AAFIS (Advanced Avionics Fault Isolation)

2. Design for BITE - NAFI

G. Deliverables

1. Tactical Display System Specification with Test Mods included.

2. Source document for Diagnostic Programs and BIT.

3 Cost/effectiveness summary comparing cost of ownership of the Tactical Display System with and without MODS.

4. Demonstration Plan

5. Final Report

   a. Cost/effectiveness summary
   b. Demonstration result
   c. Conclusions and recommendations

H. Follow-on Work - None

III. Planning Details

None contained in this sample.

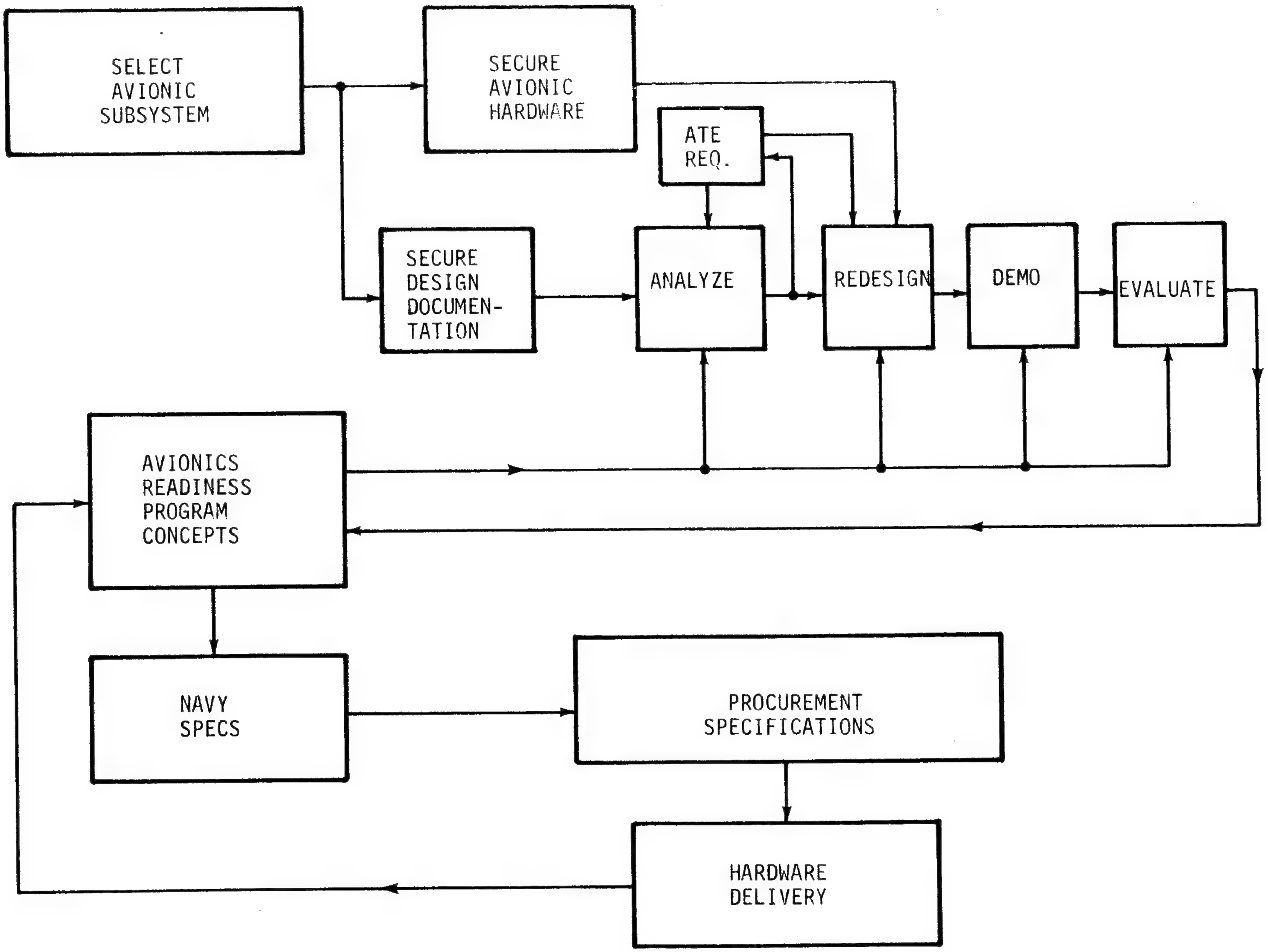

FIGURE 1. SUPPORT COMMONALITY FLOW DIAGRAM

APPENDIX B

TECHNOLOGY ASSESSMENT

CONTENTS

1.0 Introduction - In the past fifteen years, since the emergence of solid state multifunction devices, technology has increased at a phenomenal rate. Applications of these multifunction devices to computational equipment has enabled the costs of computers and their operations to become economically feasible, thereby enabling the engineering community to design, develop and construct more complex systems for an almost infinite number of applications. Additionally, this same computer capability has enabled the generation of more complex functional devices of many technologies. Hence, today's state-of-the-art is concerned with the application of MSI (Medium Scale Integration), LSI (Large Scale Integration), high voltage solid state power supplies, digital displays, charge coupled devices, etc. These are but a few of the endless types of devices and components available to the design engineer today.

Our concern here is with what will be available tomorrow. There are many factors which will affect the growth of technology. Some variables, such as technical feasibility and exotic materials have a degree of predictability. Others, such as the state of the economy and the shifting consumer market are uncertain.

In this appendix, the attempt is made to consider those areas which appear to have widespread application in the 1980-2000 year period. The approach taken is to consider the basic elements of technology. Hardware and Software, to look at the predicted schedules for application, to consider the question of sources with respect to the military applications, to consider the ability (or lack of it) to test and repair complex elements, and finally to determine methods of predicting or projecting costs associated with the rapidly emerging force.

2.0 Basic Elements - In order to approach the complex problem of technology assessment and without attempting to over-simplify the problem, technology is considered and defined in two basic forms:

a. Hardware - all components and devices used in the design and construction of electronic equipments.

b. Software - programs, programming techniques, and associated documentation used in conjunction with computational equipments for the design, operation, control or diagnosis of electronic equipment.

From these two basic elements emerge the multitude of applications of technology which have become essential to the design of complex weapons systems. The hardware element was viewed from two basic characteristics; Analog and Digital.

Analog Elements - Because of the advancements made in the development of digital devices and their applications to historically analog circuitry (such as signal processing, mathematical computations, Fast Fourier Transforms, etc.), the major areas of analog functions in the future appear to be limited to sensors, displays, and power supplies. It is conceded that analog circuitry will still be required on front end designs of equipments interfacing with a sensing element (IR Lens, Radar/Radio Antenna, Image Orthicon Tubes, etc.) as well as to IF circuitry, but from a total equipment consideration, applications of digital circuitry to the analog circuitry are readily identified. At this time, it appears that analog circuitry may be very expensive to test directly. Test program generation can be accomplished only after extensive study of the particular circuit, clear definition of the I/O functions, determination of the fault modes, setting of tolerances, and finally, determination of fault isolation procedures. Test generation functions must be manually performed since the analog simulation techniques and programs currently available are inadequate. In some cases, execution of test procedures involves extensive and time consuming manual operations. Because most faults produce non-linear circuit operation, simulation programs must be capable of

non-linear analysis, which is difficult to accomplish even theoretically. Analog integrated circuits fall into this category and modeling by replacement with equivalent components is neither accurate nor economical.

Analog modules generally are not designed for adequate testing. The major reason given by design engineers for minimizing test points is the susceptibility paths which either degrade circuit performance or render it inoperable. Not enough consideration has been given at the design level to include isolation circuitry and functions to solve the feedback/noise problem. The design of circuits using a functional approach based on system supportability and fault isolation could aid in achieving satisfactory solutions. Although it is conceded that the additional circuitry could increase complexity, cost, weight, power dissipations, etc., the application of advanced technologies may achieve satisfactory tradeoff solutions.

One system function which has a high failure rate and generates a great number of failures is the power supply. In general, (unless very stringent tolerances are imposed), power supplies are relatively easy to test functionally (output voltage and/or current). High power dissipation is the cause of their low reliability. Likewise, they are difficult to fault isolate and repair. As an example of the application of advanced technology to specific problems, SOSTELS (Solid State Electrical System) is being developed as a single, high reliability energy management system with degraded mode capability. Additionally, this function can now be treated as an individual piece of avionics equipment and can be designed for supportability in the same manner proposed for other such equipments.

<u>Digital Elements</u> - The common availability and increased speed and capability of the microprocessor will change the nature of digital circuit design. All but the simplest circuit functions will be

performed by a suitable microprocessor. Only the I/O design will be unique. It is estimated that the speed and power of microprocessors will increase tenfold by 1975 and perhaps two orders of magnitude by 1995. Storage technology will keep pace with processor development. Input/Output devices and transmission media will remain the limiting performance elements in a digital system. Additionally, interface devices are extremely difficult to fault isolate. Software, either in standard programming or microcoding, will continue to dominate the procurement and support costs of a digital system.

Testing a complex digital circuit is very difficult at present, and will become nearly impossible in future, more complex systems. Even in processing units which allow self-test capability, fault detection and isolation could provide quite difficult. This indicates that an intensive effort is necessary, in the design phase, to make the system testable. The software versus hardware cost tradeoffs in digital systems indicate that hardware BIT (Built-In-Test) is a viable alternative (or valuable complement) to diagnostic and ATE support software (reference appendix C, 3.0).

The feasibility of using expanded BIT to isolate faults to the card (module) level for digital systems has been under study for some time and the results appear very favorable.[3] Using this technique, along with a strict "design for testability" criterion, support costs could be reduced substantially and shifted in time back to the design phase, where errors are easier to detect and less expensive to correct.

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3 Advanced Avionics Fault Isolation System (AAFIS) Volume 1, August 1973. NADC Contract #N62269-73-C-0132.

This is especially true for LSI, since the cost of an LSI package is not a linear function of its complexity. For instance, adding 15% more logic to a 2000 gate equivalent LSI wafer increases the cost of the entire package by about 5%. Performing the same test functions by means of an external ATE system and a software diagnostic program would probably approach the cost of the original module. The high cost of diagnostic software indicates that BIT is an approach that should be seriously considered, since support software for a fully BIT supported system would be minimal.

Packaging - It is apparent that the present trends in electronic circuit applications will continue, and that greater circuit complexity will be packaged with increasing densities. The corresponding increase in heat generation due to the packaging densities is proving to be the limiting factor in the amount of electronic circuitry able to go on-board an aircraft. The basic packaging problem can be broken down into two areas; SRA (module) packaging and WRA (Black Box) packaging.

Module packaging presents a complex problem. The increases in circuit complexity and heat dissipation increase the cost and susceptibility to failure of the module package. This is highlighted by the present-day (thirty square inch) multilayer printed circuit board, which can hold approximately 60 MSI integrated circuits. Current logistics planning considers these cards are too expensive to throw away, but repairing them reduces their reliability. Discard/repair tradeoffs have not been accurately established. The commercial airlines are presently engaged in a serious investigation to develop a new standard for avionics packaging applications. Packaging concepts already under development by DOD and industry may provide the basis for cost effective volume, complexity, discard/repair tradeoffs. Additionally, standard modules would reduce test fixture costs and standardize ID (Interface Device) design for a large number of UUT's (Units Under Test).

Heavily interrelated with the package problem is the problem cf connectors. A large percentage of the total faults in avionics equipment is related to connector failure. Connectors today are expensive, unreliable, and sometimes difficult to obtain in quantity, especially if gold plated. Therefore, any standard packaing concept, to have validity, must consider the improvement of the cost and reliability characteristics of the connector.

Software - The cost of software has been and will continue to be a major cost factor in the operational, test and support areas. Cost effective methods of software specification, generation, documentation, and modification are presently unknown in military applications although considerable effort is being expended over a wide front to develop such methods. It is necessary that cost effective software be produced if support and readiness factors are to be improved. The concept of structured programming, as one such effort, is receiving widespread attention. Additionally, the low cost of hardware with respect to software is generating a trend toward replacing some traditionally software functions with equivalent hardware. Dedicated function microprocessors and federated computer systems are examples of this trend.

Simulation programs can be extremely valuable in the design and verification of a digital system. They can be even more valuable if a stringent design requirement for testability is imposed on the designer of avionics equipments. A good simulation program could be used to measure the efficiency of the designer's fault detection and isolation procedures, as well as the performance of any BIT in the system. The same program could be used in the acceptance testing to verify conformance to the fault isolation and detection requirements. This is much more complete and efficient than manually inserting faults, as is done today.

As an example of the present software state-of-the-art, simulation of a large digital system at the gate level is impractical, using present methods. The Navy owned LASAR (Logic Automatic Stimulus and Response) system is limited to about 4000 logic gates and costs about $5/gate total to produce a model, generate stimuli and develop a fault dictionary for a digital system.

The development of a simulation program as defined above could greatly benefit the Navy. Moreover, the development itself could be conducted as a demonstration of the most technically reliable new methods for cost effective software generation.

<u>Task Areas</u> - The analog areas which appear to have the greatest dividends and which will be investigated are:

a. The expanded application of digital techniques to historically analog circuit functions.

b. The development of computer simulation programs to assist in the design and generation of fault isolation programs for fault isolation of analog functions.

c. The expanded use of BIT (Built-In-Test) functions through the application of isolation circuitry in the basic design of hardware functions.

The digital areas recommended for investigation are:

a. Test techniques for interface and transmission media.
b. Expanded use of BIT/Microprogramming diagnostics.
c. Standards and specifications for "testable design".

The tasks to be accomplished in the packaging area are:

a. Determine the tradeoffs between physical and functional packaging.

b. Investigate and coordinate standard packaging concepts now being developed in both military and civilian areas with respect to their utility in increasing readiness of avionics equipment and decreasing its life cycle cost.

In the software area, it shall be a task of this program to determine the most promising concept of cost effective software generation and to apply it to the development of an advanced large scale digital simulation program suitable for design, test and evaluation of future digital systems. The development could be entirely new, but will probably improve and update one of the simulation programs already developed and owned by the Navy, such as the previous mentioned LASAR or the Naval Surface Research Center Logic Simulation Program.

It should be noted that the items listed above are highly interrelated, and that any investigation of one should be fully conversant with the status of the others. If the Life Cycle Cost of avionics is to be reduced and its readiness factors improved, a fully integrated systems approach is essential.

3.0 Technology Schedule Projections - Making a detailed and complete projection of what technologies will be commonly available in the 1980-2000 time frame would be quite difficult, if not impossible. What can be done, however, is to consider the technologies presently being used or introduced into the market, and making estimates of

their later availability in production quantities. The development of new technologies and the decreasing time span between development and production suggests that the list is not comprehensive, and should be updated regularly.

One estimate that appears solid is the LSI will become much more common, and will dominate the integrated circuit market, especially in the digital areas. Both full wafer and hybrid technologies will be used in LSI packages. CMOS (Complementary Metal Oxide Semiconductor), MNOS (Metal Nitride Oxide Semiconductor), NMOS (N-Channel Metal Oxide Semiconductor), CCD (Charge Coupled Devices) will all probably be in general use by 1985. In the optical area, holographic storage devices, fiberoptic transmission media, and optical signal processors will be fully developed and commonly available.

At the basic physics level, the devices identified are fairly well categorized and described. However, their fault modes and characteristics under failure conditions have not been adequately investigated. It would be beneficial, therefore, to invest in some basic research in these areas, with a view towards determining production procedures and techniques that would result in more reliable devices as well as fault detection at the basic component level.

Another salient point for consideration is the time span of electronic technology from the development phase through production as opposed to basic technological changes in the airframe or engine of a military aircraft. The lifespan of an airframe is several times that of the avionics technology used within it, and this trend is likely to intensify in the future. It will therefore be

necessary (threat driven) or desirable (cost driven) to periodically update the avionics complement of an aircraft. The specification, procurement, and support of an aircraft weapons system should be developed with the basic tenet that the avionics will be updated in the future, and may even be replaced by a totally new technology.

Task Area - The task recommended is the compilation of a technology projection summary, including, for each technology, introduction dates, characteristics, production methods and tooling, potential applications, principal sources, cost trends, failure modes, and potential support problems. This summary would serve as a basic reference document for all activity under this plan.

4.0 Manufacturing and Sources - Up to very recently, technology advances in electronic circuitry have been driven by military applications. With the present dramatic increase in consumer electronics, for example in the automobile and calculator markets, it appears that this is no longer the case. It is quite possible that future developments of exclusively military electronics, with its stringent environmental specifications, will be prohibitively costly. In addition, since consumer electronics is usually either throw-away or repaired at the factory under warranty, there is no control over internal changes or improvement in the circuitry. Such a change to a military unit would, of course, require redesign and reprogramming of the test software, a very costly proposition. Warranty of military avionics may necessitate a throw-away/factory repair philosophy at higher assembly levels if the problems of internal configuration control at low cost are to be solved. If the military is to live with consumer electronics, and reap the concurrent cost benefits of large-scale production, a new philosophy of test and environmental specification will have to be developed.

It will be necessary to thoroughly investigate present technologies and trends in consumer electronics, and determine where and how electronic circuitry produced for the commercial market can be used in military applications. Some cost tradeoffs to be considered are:

a. Using commercial electronics with reduced performance and environmental factors.

b. Funding the manufacturer to incorporate the necessary functions in commercial electronics.

c. Developing government-owned production facilities.

It should be noted that the above options are not mutually exclusive. They should be applied depending on the requirements of the application. What is necessary is a procurement procedure that considers the options available and makes the necessary life-cycle tradeoffs. As an example, suppose an environmental metal analysis of a particular application indicates that a standard automobile microcomputer system could be used to perform a circuit function. A Life Cycle Cost analysis then reveals that the expected changes, improvements and modifications to the commercial system would increase the software support cost to the point where it would not be economically feasible to use it. Some options available are:

a. The government could produce the circuit at its own facility.

b. The government could fund the manufacturer to design and incorporate BIT in the system to eliminate the requirement for test software.

c. The system could be totally supported by the manufacturer on a long-term warranty.

A further life cycle cost analysis could indicate the correct choice.

It can be concluded from the example given that a flexible procurement policy or philosophy with adequate life cycle cost predictions and measurement techniques is of primary importance. This is in accord with the recommendations of the Electronics-X Report. If the recommendations of the report are incorporated by DOD, the later incorporation of a life cycle costing model would be relatively smooth and uncomplicated.

Task Areas -

a. Development of Life Cycle Cost parameters are related to the procurement and support options listed above. These parameters will be incorporated into the life cycle cost model developed in appendix F.

b. Investigate present environmental specifications with respect to the technologies projected for the years 1980-2000. Coordinate results with the recommendations of appendix E.

5.0 Test and Repair - It appears certain that the trend toward using general purpose, programmable ATE (Automatic Test Equipment) for the testing of avionics will continue throughout the 1980's. The equipment itself will have a heavy proportion of LSI circuitry, and thus will be nonrepairable below a significantly high level (2000-5000 transistor equivalent). A module will probably consist of a fairly

small number of LSI packages, and an SRA will probably be a functional unit consisting of 1-5 modules. The result of this high proportion of nonrepairable packages will be that fault detection, rather than fault isolation, will be the principal function of ATE. Repair will consist of replacement of the faulty unit. SRA repair may be attempted at the organizational level, but modular repair should be discouraged. The throw-away or repair decision will have to be evaluated according to life cycle cost analysis and required skills.

The traditional method of deciding whether a faulty piece of electronic equipment should be discarded or repaired was based on a cost/reliability figure. This approach is further based on the assumption that repair costs were relatively constant over the life of the unit (i.e., the first repair cost only slightly more than the tenth). This assumption is not true when the unit is tested and repaired using programmable automatic test equipment. The software cost of producing the test program set (cost of first repair) is by far the most expensive item in the maintenance life of the unit.

For example, since this software cost is usually unknown until after the program is complete, the Program Manager may be presented with a situation in which a module would have been classified as throw-away if a true estimate of the test program set costs was known. Having purchased the test program set, the Program Manager is now trapped into accepting and paying for test program changes that result from modifications and updates to the equipment. Such a situation can be avoided if an accurate method of estimating software support costs is developed.

Another problem that will face a weapons system development program is the support questions raised by a form, fit, and function

specification for avionics equipment. Two units can meet all the form fit and function requirements of a specification and have two entirely different test program sets. The result is unique support for common equipment.

Task Areas -

a. Develop techniques to quantitatively determine best test/ repair methods based on advanced technology.

b. Apply and correlate the results of the life cycle costing development effort of appendix F, and the BIT study (appendix C) to the problems discussed above.

These are two ways this problem can be circumvented. Either the interface to the test program set can be specified as part of form, fit, and function, (this is feasible with sufficient BIT incorporated into the equipment), or the equipment can be spared as a unit, and maintained by the manufacturer under a long-term warranty.

It is apparent from the above that costing techniques must be developed to the point where the impact of software support costs can be accurately preducted. Also, they should consider tradeoffs involved in a long-term warranty as opposed to a higher unit acquisition cost resulting from a fixed, specified test program set interface.

6.0 Cost Indices - As the technology assessment/forecast task progresses within the structure of this Avionics Readiness Plan, it is imperative that methodologies and techniques be simultaneously derived that will allow the relative impact of technology growth

on cost to be ascertained. The program management must project the future costs of weapon systems and their related support systems. Since systems to be designed, procured, and operated in the 1980-2000 time frame will contain new technologies, cost analysis must develop the means of adjusting conventional cost estimating techniques to account for changes in expected design and production methods due to advanced technological applications. Such adjustments to present cost projection relationships are known as cost/technology indices.

Just as the stated objective of the technology assessment/ forecast section is to determine the direction and speed of technological growth and its impact on future systems and system diagnostics, so the objective of cost/technology indices is to determine the impact on cost (Development, Production, and Operating) of hardware and software technology changes. Indices are constructed, in general, such that a base year is represented by 1.0 with each succeeding year expressed relative to that base year. The developed cost indices are based upon the subject category of equipments performing "today's" functions with "tomorrow's" technology. Figure 1 provides a sample composite cost index for IFF equipment as portrayed in Information Spectrum, Inc. Report entitled "Development of Airborne Communications Equipment Cost/Technology Indices" (U), dated 15 January 1974 under NADC Contract N62269-73-C-0301.

Figure 2 describes in flow chart format the methodology employed in the development of cost/technology indices. To date, development work at NADC in the area of cost/technology indices has only taken into account typical Production costs for hardware items, and does not reflect the cost of Research and Development

or Operations. However, there is no reason to believe that similar methodology and indices cannot be developed to cover those areas of cost (R&D and operations) not previously addressed. Similarly, cost/technology indices relating to cost for software items must be researched and developed since software is rapidly taking over the major functional operations in airborne weapon systems and support systems.

Valid cost effectiveness/cost benefit analysis relative to new weapons systems and support system development, procurement and operations must be conducted in order to provide program management and high level DOD review authority with a clear picture as to a proposed system's worth. As technology advances, methodology must be developed to assist in the projection of costs relative to these technologies. It is felt that the proposed cost/technology indices will partially satisfy this requirement.

The most logical approach to gapping the void created in cost estimating due to advanced technology is to develop cost indices for many and varied hardware and software systems (both prime and support) to be considered within the Avionics Readiness Plan for the 1980-2000 time frame. Cost indices can be for either general or specific categories of systems as the need arises. Figure 3 shows functionally how cost/technology indices can be utilized to enhance advanced cost estimating techniques when technology changes will be a significant cost driving factor. Existing and new CER's (Cost Estimating Relationships), some to be developed under the efforts of the Avionics Readiness Plan, can be modified by the cost/technology indices to provide a more valid account of future systems cost.

Task Areas -

a. Survey and determine the most productive areas for cost indices development for application to costing in support of other tasks identified in this Plan.

b. Development of specific methodology required to achieve the establishment of meaningful cost technology indices in specified technical areas. Literature survey and exhaustive dialogue with engineering personnel. The primary purpose of this task is to ascertain how specific expected technological advances will affect cost.

c. Application of developed cost technology indices to cost estimating process in support of the Avionics Readiness Plan. Specific program assumptions and constraints will be factored into application of indices as required.

d. Tracking and validation of developed indices, where possible, to determine precision and resultant adjustment criteria for existing and future cost technology indices.

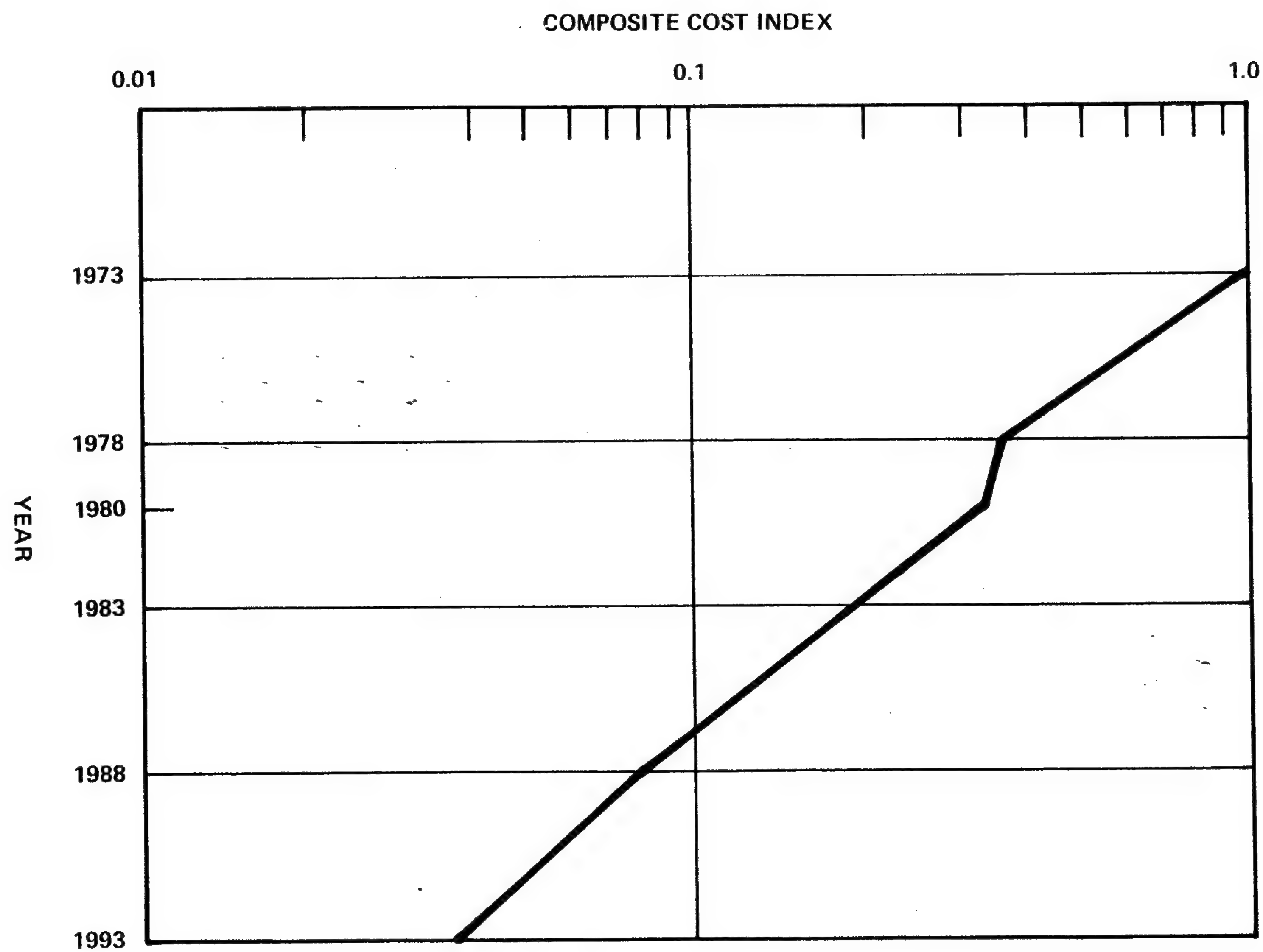

Fig. 1. IFF Equipment Category Composite Cost Index

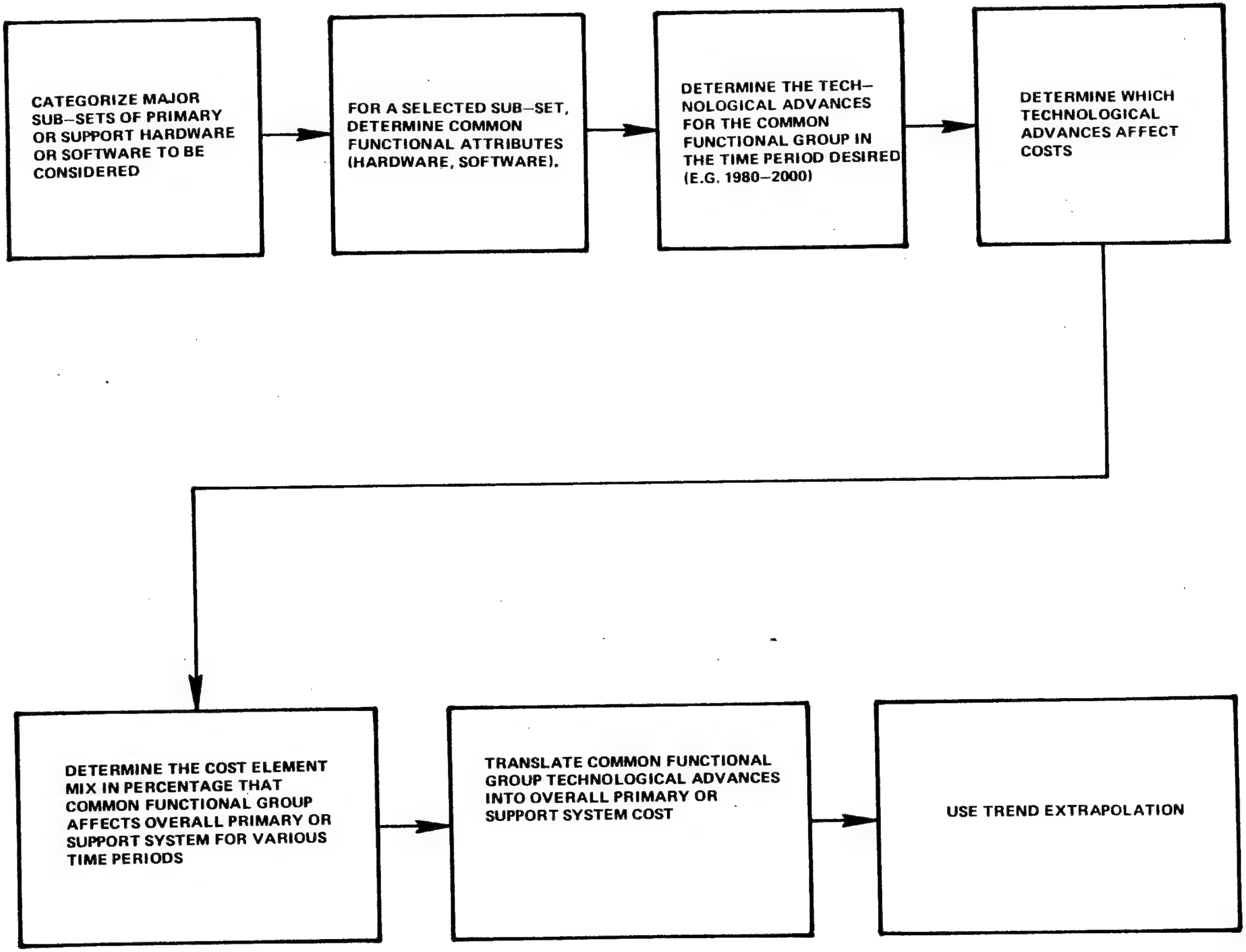

Fig. 2. Flow Chart of Methodology for Developing Cost/Technology Indices

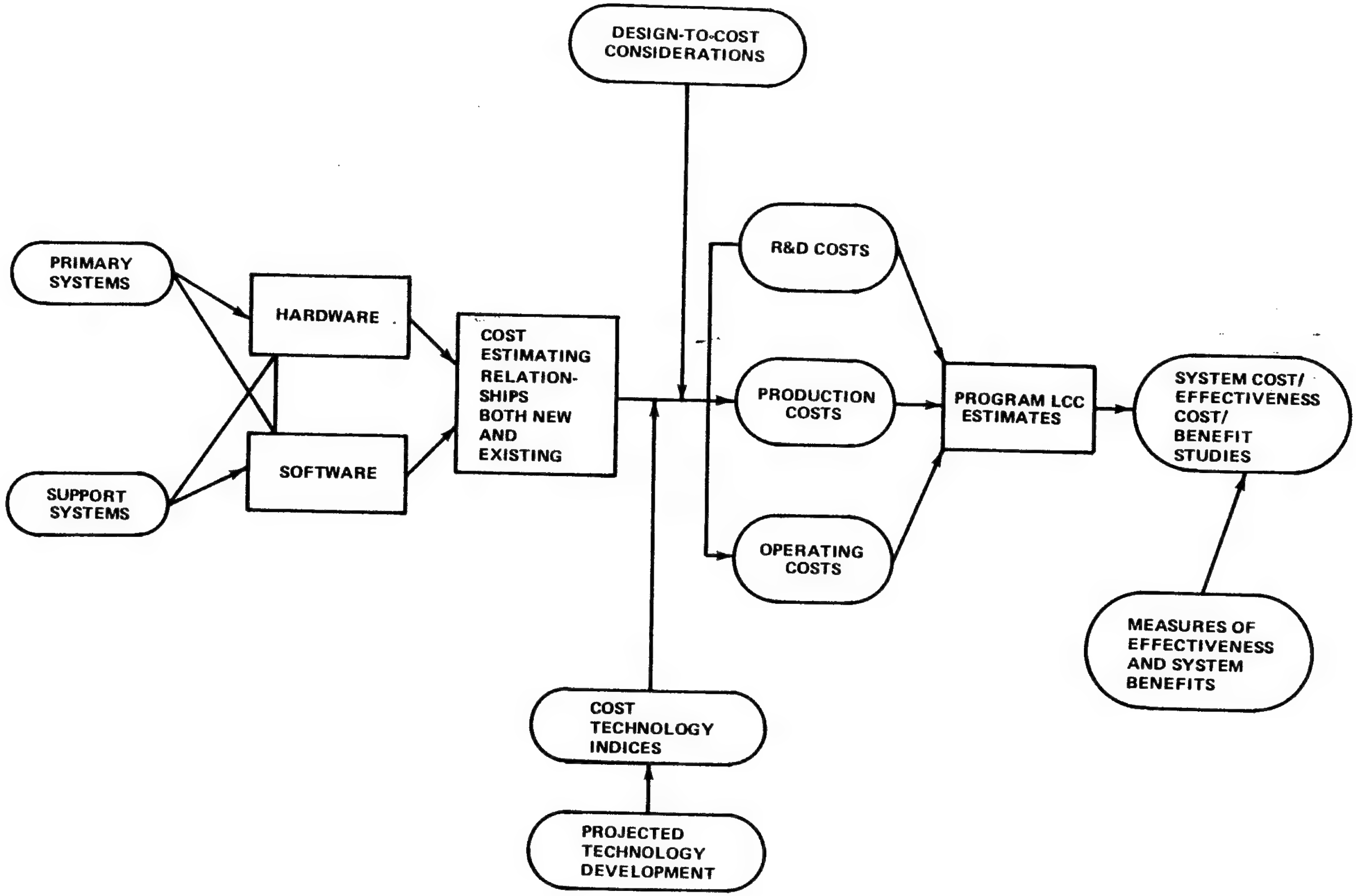

Fig. 3. Interrelationship of Cost Technology Indices with Advanced Costing Methodology

APPENDIX C

TECHNOLOGY APPLICATION

CONTENTS

1.0 Aircraft Systems Test - There are three test categories that will be considered under the heading of Aircraft Systems Test:

a. Readiness Testing: Testing to determine functional presence and acceptable performance of functions.

b. Diagnostic Testing: Trouble shooting tests performed to isolate a faulty or out of tolerance component.

c. Specification Level Performance: Testing to determine figure of merit or establish proof of performance relative to specified performance values.

The term aircraft is used here to indicate organizational level testing of avionics and does not imply that the aircraft itself is the object of test. Testing that is performed in flight, i.e., IFPM is treated in appendix D, section 2, Avionics Testing.

The potential impact of advanced technologies on the test function at the organizational level is an area that requires high priority attention, for it is at the organizational level that the maintenance chain starts. Proper exploitation of the test function at this point potentially can relieve or eliminate the requirement for certain tests at other levels of maintenance.

Definitions and general goals for each of the three categories of test are contained in the following paragraphs.

Readiness Test: All those tests, both programmable and fixed, software and hardware, automatic and manual, that provide for determination of functional presence and measure of functional performance, immediately prior to commitment of the weapon system or subsystem to the mission.

In order to facilitate usage of the Readiness Test by Navy operator personnel, the following capabilities should be considered when designing the Avionics subsystems and systems. Inclusion of BIT or software test features that enable these capabilities is desirable.

a. Scope: The Readiness test should provide for the testing of all equipment functions and modes, including input and output functions. There should be no element of the system left untested.

b. Quality of Test: The objective of Readiness test is to measure equipment performance to the extent that crew personnel can make a mission GO/NO-GO decision. Often the time and facility constraints at the organizational maintenance level prevent crew personnel from conducting a test which will measure equipment to "specification" values. Readiness tests provide the ability to test the equipment to an "acceptable" level of performance, with the more stringent specification test conducted somewhere other than the flight deck or hangar deck. In order for the Readiness test to be suitable for maintenance application, it should have the following general features:

(1) Day to Day Repeatability: If at all possible, the consistency and long term stability of the test should be an order of magnitude better than the equipment.

(2) Channel to Channel Consistency: Where the equipment has several channels, the Readiness test should provide identical stimulus and measurement to each. Results should be compared.

(3) Performance Assurance: In the interest of time and procedural simplicity, the test requirements can be relaxed to a

point where results can be obtained rapidly and positively, e.g., test signals are 2-3 db above MDS. However, the relaxing of the test should not be to the degree that allows the equipment to greatly depart from design performance. The Readiness test should be stringent but not impossible or impractical at the organizational maintenance level (reference appendix D, 2.0).

(4) Accuracy: Where possible, accuracy of stimulus and measurement should be an order of magnitude greater than the acceptable accuracy of the function under test.

(5) Resolution: The resolution of the test stimulus and measurement must be suitable for the required accuracy. Many of these features are not obtainable within today's state-of-the-art, especially in the analog area. Advanced technology should provide test quality improvement.

c. Graduated Test: The Readiness test should be designed to provide the necessary information for the operating crew to make a GO or NO-GO decision with respect to prosecution of the mission. As such its primary objective is to provide an accurate description of the capability of the system. In digital areas where nonambiguous test results are available, the results may be displayed as operable (GO) or nonoperable (NO-GO) functions. However, in areas where sensitivity, figure of merit, alignment, etc. is the essential parameter of the function being measured, the results should be presented as amount of departure from normal, with no judgement by the Readiness test program as to the GO/NO-GO status of the system. In areas subject to drift and degradation, the test should measure the actual performance of the function and present it to the operator for his determination of systems readiness. Implicit

in the test results is nonambiguous identification and location of the function tested as well as the measure of the functions performance.

d. Independency: The readiness test should be designed so that it has degraded mode capability being able to operate with only partial availability of equipment, i.e., it is not necessary to have all equipments operating in order to proceed with portions of the readiness test. To the maximum extent practical, each major portion of the equipment should have the capability of being tested without direct dependence on other portions of the system. Alternative test modes should be available (BITE, Manual modes) when computer generated test modes are not available.

e. Procedural Simplicity: The test should be designed to be used by Navy personnel who have minimum operator training and experience. The test should be self leading and instructive, not requiring excessive use of manuals. Where programmed instructions, cues, alerts, or data are displayed, and where operator input to the program is required, the Readiness test should be such that all communication is in plain English and numbers, not requiring interpretation, translation or other indirect means to transfer the desired intelligence.

f. Test Transition: The Readiness test should be transitional or progressive in nature in that it directs the operator to the next level of testing and provides the necessary continuity to efficiently initiate that test. Upon determination of a fault condition, the readiness test should clearly indicate the nature of the fault, the general hardware location, the function, and when diagnostic testing is appropriate, reference to the appropriate diagnostic. Care must be taken that the operator is not left

stranded at the conclusion of the readiness test, knowing that a fault exists but not having the slightest notion or indication as to the next step. The Readiness test shall be coordinated with all levels of maintenance publications, procedures, and programs, facilitating cross references and transition by the technician as he proceeds from one program to the next and from automatic to manual routine.

Diagnostic Test: Diagnostic test, in its broadest sense, consists of any test action or combination of actions that have as their specific objective the identification and location of faulty components. Diagnostic test consists of programmable and fixed, software and hardware, automatic and manual test modes. In a more narrow sense, diagnostics are often assumed to be only those tests that are computer generated and/or controlled. For purposes of this test, diagnostics will be used in its broadest sense.

Historically, fault location testing has been confined to levels of maintenance higher than the organizational level. It is suggested here that a requirement exists to perform fault location to the SRA at the organizational level. The advanced technologies offer both opportunity and practical capability to achieve this goal. With increasing complexity of integrated avionic systems, false removal rates of WRA's will also increase. Isolation to the next lower assembly will significantly reduce the WRA false removal rate. Additionally, the increased functional capability at the SRA level, and improved packaging techniques may make the SRA the more desirable WRA in future systems. In this regard, the SRA failure rate/cost ratio may be substantially less burdensome to the logistic system, especially if some level of commonality is achieved.

Assuming for the moment that diagnostics to the SRA is feasible and achievable at the organizational level, the avionics design should contain features which allow the following test capability:

a. Time Constraint: Diagnostic tests at the organizational level must be completed within the same time limits required by readiness test.

b. Implementation: The Diagnostics would be structured in form like the Readiness test, except that it would be at a lower level of detail. It should be no more complex to operate than the readiness test. Its application would be at the subsystem or WRA level as opposed to the whole system level of the Readiness test.

c. Test Transition: The Diagnostic test should be designed such that it is complementary to the Readiness test, capable of directly using Readiness test results to identify the equipment area to be tested. Where software is used, consideration should be given to automatically saving the results of Readiness test for rapid access to the diagnostic test. Additionally, automatic transfer to diagnostics from Readiness test should be considered when such transition can be under the monitoring control of the technician.

d. Test Control: The control and management of all tests is the responsibility of the technician. Where software is used, major test mode selection shall be determined by the technician.

To achieve the diagnostic capability described above, design of the prime avionics must be highly cooperative with the test objective. Current technology does not permit full diagnostic

capability in many avionics applications; advanced technology may allow this capability to be achieved in a larger number of avionic equipments.

Specification Level Performance Testing: Testing to specification requirements by organizational activities consists of all those tests and facilities necessary to measure the equipment for functional presence and performance to the requirement of the equipment and/or weapon system performance specification. It may include hardware or software, manual or automatic, programmable or fixed tests.

a. Specification Level or Figure of Merit: Specification Level or Figure of Merit testing at the weapon system level is not normally performed by Naval activities at any maintenance level. The closest approach to weapon system testing is the individual testing of boxes at an IMA or Depot facility. The assumption is made that all other boxes in the aircraft with which the UUT interfaces and all aircraft wiring harnesses are at full specification capability. Such is seldom the case. However, since no such tests are formally conducted, operational activities are never fully aware of how good, or how bad, the system really is.

b. Speed of Execution: Specification testing should be performed periodically as part of the organizational activity's scheduled maintenance routines. Such testing could be done during check periods, when the aircraft is available for more than a day. There is no time limit on specification level testing. Due to the time consuming and methodical nature of the test, subtle and marginal offenders that slip through Readiness and Diagnostic test will be discovered and isolated.

c. <u>Test Objective</u>: The specific purpose of specification level testing is to provide the organizational level activity with periodic <u>Figure of Merit</u> or <u>Certification of Performance</u> data on the system avionics capability, thereby establishing a reference for operational performance standards.

d. <u>Test Results</u>: All test results will be stated in terms of departure from the performance capability required by the equipment and/or weapon system specification.

e. <u>Scope of Test</u>: The Specification tests should thoroughly exercise all elements of the equipment in all of their modes. Included as an integral part of the specification test is an end to end system test capability, designed to establish Figure of Merit for the next higher systems level, e.g., Specification test for the acoustic processor, should also include a specification type test for the entire acoustic chain, including sonobuoy receivers, signal distribution amplifiers, etc.

f. <u>Test Commonality</u>: The program routines, operator procedure and test procedure used for Readiness test should be duplicated by the Specification Test, to the greatest degree possible. Readiness test may be considered as a subset of Specification test, similar in architecture but abbreviated in procedural steps and time.

g. <u>Special Support Equipment</u>: To the maximum extent practical, the Specification test should not require the use of Special Support Equipment. Where test signals are required, consideration should be given to their inclusion as part of the BIT. Practical limitation in certain analog and RF areas may exclude this capability. Discreet application of Figure of Merit

testers may be necessary. Extreme care ought to be exercised in the area of SSE as it represents the opportunity to create a larger problem in support and maintenance of the testers, than value derived. Every opportunity ought to be pursued in the application of advanced technologies at the BIT level to achieve specification level test capability.

This discussion on Aircraft System Test has suggested a few departures from normal maintenance operation and procedure. Emphasis is on problem resolution to the least functional level through use of self contained test features. This approach can be made feasible only where advanced technologies are fully applied to the test and maintenance function.

Task Areas -

a. Comparison of mission acceptable limits of operation to specification limits of operation for each avionic application.

b. The establishment of boundaries and requirements for performance testing of mission essential function at the organizational level. Make recommendations as to types and extent of self contained test capability to achieve satisfactory Readiness, Diagnostic, and Performance test capability. Investigation of advanced technology devices for lightweight, compact, accurate test function generators.

c. Develop a compatibility between test functions, operational functions and mechanical modularity. Establish guidelines and develop specifications for most favorable test and repair capability at organizational level.

d. Development of methods whereby readiness testing can be merged with or otherwise interfaced with diagnostic testing at all maintenance levels.

e. Development of actual test functions and devices where inadequacies are found in paragraph b. above.

2.0 Built-In-Test Versus Shop Testers - This section considers the tradeoffs between test features contained in Avionic end items and the test capability contained in the Avionics ship. The relationship should be one of complement and cooperation rather than opposition. It is suggested here that the test features at the O-level can have great influence on the ease with which subsequent testing is accomplished at the higher maintenance levels.

BIT (Built-In-Test) has the problem of assumed limitations, and is often treated as only a characteristic of the avionics black box. Additionally, it is assumed to be a hardware function, and while this is often the case, BIT can and does manifest itself in broader form. An alternate term "Self-Contained Test" is introduced into the text to express ideas that are not normally conveyed by the term BIT. SCT (Self Contained Test) is herein defined as the capability to perform test functions within the limits and capabilities of the organizational activity, the weapon system, the avionics subsystem, and the individual WRA/SRA. SCT includes BITE, Diagnostics, IFPM, Readiness Test, etc., as subset functions. Loose or separate test equipment, such as GSE or SSE, is strictly excluded from the definition of SCT. SCT functions at the weapon system, subsystem, or WRA/SRA level may include both hardware and software.

The objectives of SCT can be categorized as follows:

a. Execute the measurement of systems capability at the organizational level to the extent that Systems Readiness is determined without ambiguity.

b. Determine the presence of malfunctions and marginal operation. Indicate the location of the faulty assemblies to the WRA/SRA level, with minimum ambiguity.

c. Provide avionic status inputs to the operating system for the purpose of degraded mode assessment and dynamic functional reconfiguration.

d. Enhance the planned philosophy of higher level maintenance (I-level, Depot level, Factory level) to the extent that testing requirements at these levels are substantially relieved, if not eliminated altogether.

SCT in current avionic systems has been poorly implemented, barely satisfying the objectives of organizational level readiness and diagnostic testing. The requirement to assist Intermediate or Depot level maintenance has been ignored.

Ideally, the only maintenance required should be in and around the aircraft and within the capability of the operating squadron. Practically, multiple levels of maintenance are required to support the avionics. Current weapons systems cannot attain independent test and maintenance capability. Limitations are due to many factors and conditions.

a. Operational requirements (at sea, long supply pipelines)
b. Physical limitation (weight, volume, heat)
c. Technology (inadequate stimulation and measurement capability)
d. Economics (high failure rate to replacement part cost ratio)
e. System Design (functional partitioning, diagnostic limitations)
f. Mechanical Design (poor functional packaging)
g. Installation Constraints (poor access to WRA's and SRA's)
h. Aircraft Systems (inadequate heat management and poor quality primary power)

These problems and others cause a high failure rate at the aircraft and reduce the capability for test and repair.

Advanced technologies contain many of the essential characteristics that directly attack the problem areas above and offer the opportunity for self-contained test. Discussions relative to the application of SCT/BIT as it pertains to both aircraft and shop are contained in appendices C and D.

Specific examples of cooperative testing between maintenance levels are:

a. Fault isolation by SCT to the SRA at the O-level maintenance. The WRA/SRA, upon entering the I-level maintenance, can proceed directly to the ATE module tester, bypassing completely the WRA/VAST stop. Should the SCT be developed to the degree that there is little or no SRA ambiguity at the O-level, then the return path, repair verification stop at the VAST could also be avoided. This capability is generally beyond avionics maintenance design and SCT test capabilities for current fleet systems. It is well within the capability of future systems and is in principle being achieved in selected applications on P-3C aircraft today.

b. Coordination of aircraft test results and SCT maintenance tapes with I-level testers. Each time readiness and diagnostics are run on the aircraft, a health and status tape would be generated for use at the I-level activity. The results of such tapes could be fed into the ATE to the end that:

(1) The correct ATE application program is automatically selected.

(2) The general fault location and symptom provided the ATE is used to access the most efficient point in the program for test initiation.

(3) The ATE is sensitized to particular historical fault modes and combinations, (i.e., input buffer receives data intermittently) allowing iterative testing or special test configurations to be implemented by the ATE.

c. Where SRA Reliability/Cost factors are sufficiently high to warrant throw-away maintenance philosophy, the SCT would pursue the location of the fault to the SRA at the O-level, bypassing the entire I-level activity for that application.

Task Areas -

a. Development of the routines and interfaces necessary to the continuity of testing between aircraft and higher level maintenance.

b. Projection of avionic technologies and applications that exhibit the greatest potential for throw-away or Depot repair subsequent to O-level maintenance. For each of these technologies and applications, detail the specific test requirements necessary to the success of that maintenance philosophy.

c. Determine those future avionic systems that may have continued and fundamental dependence on I-level and Depot level maintenance. For each application and technology, determine where new and/or improved test capability and ATE developments will be required.

d. Where new ATE may be required, show alternative approaches, and cost tradeoffs between various levels of SCT and ATE.

3.0 <u>BIT/Reliability Trades</u> - In most of the recent weapon system designs, BIT (Built-In-Test) and Reliability goals have been set and implemented by a group of engineers totally separated from the principal functional design team. As a result most of the BIT features designed into the system do not effectively cover the logic function by function. The completeness and adequacy of the self-contained test functions are presently dependent on the amount of test circuitry <u>added-on</u> after functional design to monitor the functions and perform the tests. This approach "adds-on" to the complexity of the unit and reduces its reliability. Most of the tradeoffs in BIT and Reliability are made on their parameters by Reliability and test engineers independent of the functional logic and the design concepts. Costs and delivery schedules additionally dictate parameters that determine the level of testing, reliability and their tradeoffs, independent of the performance design concepts and the application of the selected technology.

The BIT and Reliability goals should be set at the system definition and implementation phase and be an integral part of the functional design. This approach should be taken in order to incorporate a BIT capability at a fundamental level rather than as an add-on feature. This capability can be implemented simply and at a relatively low cost. The present system's design approach makes BIT and Reliability tradeoffs costly and ineffective since they represent ficticious parameters that are not bounded by the rest of the system.

Since the BIT features and the reliability goals are usually set around the general characteristics of the technology utilized, it does not adequately cover the system due to the lack of a meaningful connection with the functional application of the technology. This approach restricts self-test functions by the allocation of the functions and their physical packaging rather than the depth required to adequately do the job. The BIT requirements are presently very vague to their structure and approach. It is not clear whether tests are self-contained, require external test equipment, or to what level the tests are contained in software or hardware functions. The specific types and method of tests are inconsistent and vary widely across the systems. These inconsistencies create manpower and training problems, inhibiting the airman from applying his experience gained in one weapon system to another application.

Activities chartered with the technical planning and development of the future weapon systems should develop the expertise to guide industry to implement BIT as a principal function in the earliest development phase of the system. The introduction of LSI (Large Scale Integration) in quantity and at reasonable costs will cause more functions to be implemented in hardware including self-contained functional tests. Most of the new integrated circuit development is being driven by commercial rather than military demand, resulting in higher volume at lower costs. (Refer to appendix B.[3]) The military community should take advantage of these new circuits to achieve any sort of electronic's technology standardization at lower costs in the development of future systems. Research funds should be allocated in standardization of the electrical, mechanical, and environmental specifications across common weapon systems and platforms and for the inclusion of standard BIT approaches.

3 Electronics X - A Study of Military Electronics (IDA Report R - 195)

Task Areas -

a. Explore the feasibility of developing mathematical tools for the design of integral BIT functions (i.e., a complementary theory to Boolean Algebra).

b. Determine the tradeoffs involved in BIT inclusion as an integral part of the conceptual design phase vice separate/sequential BIT design.

c. Determine those technologies most amenable to integral BIT features.

d. Determine the effects of BIT inclusion on reliability and performance.

4.0 Shop Tester Requirements - The Navy's primary shop tester, afloat and ashore, has been designated AN/USM-247, VAST (Versatile Avionic Shop Tester). VAST is an automatic test system which contains all of the stimulus/ measurement functions deemed necessary to support avionic systems on the drawing board in the late 1960's or planned for the near future. The stimulus/measurement functions and systems engineering are basically late 1960's to early 1970 technology. Test repeatability and automatic decision making consistency through the use of computerized test programs has produced a uniform and standard test capability throughout the fleet. The Navy has achieved many of its original objectives and realized many benefits from VAST, but has also encountered many unanticipated problems, such as software test program development and the design of ID (Interconnecting Devices), which mate the Unit Under Test to VAST.

The Navy has recently developed a new module tester, HATS (Hybrid Automatic Test System) to off load the VAST from an increasing SRA workload. The increased SRA workload from the S-3A

weapon system and the limited throughput of VAST necessitated this development. HATS is scheduled for introduction into the fleet in mid-1975, but is currently experiencing the same general problems in software test program development and ID design that was seen on VAST.

As avionics technology changes the capability and effectiveness of VAST and HATS must continuously be appraised and evaluated. When avionics technology exceeds the capabilities of these systems or when the cost of ownership becomes prohibitive, extensive modifications or replacement may be necessary.

Should major modification or replacement of the currently available common ATE become necessary the following features should be considered in the updated shop test system:

a. Federated processing/control architecture

b. Stimulus section tailored to avionics

c. Standardized functional interfaces

d. Measurement section tailored to standardized functional interface

e. Expansion capability to allow the addition of new stimulus, measurement, or processing functions

f. Single operator capability

g. Hard copy printout of test results, and necessary repair action

h. Multiple UUT test capability

i. Modular construction for ease of repair and tester expansion

j. Use of standardized components and circuitry

k. Continuous self test with fault isolation routines

The federated processing/control system should consider use of minicomputers for the highest level of system processing and microprocessors for control functions and complex algorithms. (See appendix D, section 5.0.) This will reduce the software control requirement, decrease test time, and provide greater versatility in the operation of the ATE system. This type of architecture also increases the expansion capability of the system.

The stimulus and measurement sections shall be designed to satisfy the standardized functional interfaces of future avionics systems. These sections shall be miniaturized and packaged to support individual functional requirements. The control format and hardware configuration should be designed for ease of maintenance. It should allow expansion, permit multiple UUT testing, and use standard circuits and components wherever possible.

The next generation ATE system shall also include human engineering features which will allow a single operator to perform all necessary actions while the UUT is connected to the station.

A hard copy printout should be provided to record the results of all tests completed, those passed as well as those failed.

They will provide a permanent record of all UUT's tested for 3M processing, supply, and design evaluation of problem areas.

The ATE system should also contain a continuous monitoring technique which is capable of assuring minimum performance operation and detecting failures at the functional level. Once a failure is detected, a second routine should automatically fault isolate down to the replaceable assembly. Each of these routines shall alert the operator of station condition and repair action necessary.

It should be stressed, however, that design of a replacement automatic test system is not the objective of this program. Every effort shall be made through avionics design constraints to utilize the existing ATE where possible or eliminate or reduce the requirement for a shop tester.

Common Automatic Test Equipment can, with proper design, provide the user with a number of direct and indirect advantages (see table I) not realized with the previous use of SSE and GSE.

During the next decade Navy management must address and continuously assess the adequacy of the fleet designated ATE systems. As avionics technology advances, ATE modifications, changes, added capability and deletion of outdated technologies will force the cost of ownership to change. The Navy must determine as technology changes whether it is more cost effective to modify and update current systems or whether it is time to develop a new ATE system to replace those in existence. Therefore, a measure should be devised to aid in this decision, and should include:

Table I

Direct Advantages		Indirect Advantages	
a.	reduces variety of support equipment	a.	reduces avionics hardware test time*
b.	reduces quantity of support equipment	b.	reduces repair time*
c.	reduces shop space	c.	increases consistency of testing
d.	reduces storage space	d.	reduces shop management and control
e.	reduces ATE spares support	e.	allows competitive bidding on test program development**
f.	reduces number of maintenance personnel and technical level	f.	allows early Navy support of avionics hardware***
g.	reduces training requirements*		
h.	reduces Technical Manual requirements*		
i.	reduces test development cost*		

* Depends on avionics design for testability and ATE compatibility and the test programmer's ability to provide minimum testing while satisfying performance and diagnostic fault isolation test requirements.

** This can be accomplished if the avionic supplier is required to design test ability and ATE compatibility in the Avionics hardware, demonstrates their capability during design approval and provides acceptable and verified diagnostic test flow diagrams and supplemental data on or before the delivery of the avionics end item. (See appendix D, paragraph 4.0.)

*** This assumes early availability of test documentation and early procurement of test data.

a. Cost of hardware modification.

b. Cost of associated software modification.

c. Cost of new common ATE to satisfy support requirement.

d. Impact on areas specified in section II, table I.

The Avionics Readiness plan shall address this problem and provide a plan which will assist in making cost effective, timely decisions.

Task Areas -

a. Develop alternatives for future ATE modifications or replacement.

b. Develop a federated ATE systems concept, hardware and software.

c. Develop a plan for test program development from factory test through organizational testing.

d. Make periodic assessments of test program development and adequacies of current ATE systems and make recommendations as required.

5.0 Maintenance Philosophy - The stated maintenance philosophy for any avionics system or subsystem should take into account; operational, environmental, application, support, and organizational factors as well as its own functional and technical factors. There is a best maintenance philosophy for each avionics end item as applied to its operational environment.

Avionic systems currently in the fleet require a demanding support effort to keep them operational. In some cases the maintenance philosophy imposed by the fleet is completely different than the one envisioned by the designer. In other instances the intended maintenance philosophy has been implemented but its effectiveness is low. In either case there is a serious mismatch between the intended support capability and the actual support. Mismatches in maintenance philosophy between designer and user cannot be tolerated in future avionic systems where rising costs and increased complexity will make the support burden even more difficult. In the following text some causes of today's mismatches will be considered followed by brief discussions on effort necessary to develop suitable maintenance philosophies for advanced technologies.

Today's avionics procurement specifications are poorly written in both the maintainability and supportability areas. The typical maintenance concept is stated in generalities and is not specifically related to the proposed equipment application, appearing as an afterthought and not taking advantage of the equipments technology and architecture. Maintainability requirements in specifications often manifest themselves as wholesale callouts of AR-10A, which is a general maintainability specification, and requires tailoring to each application and operational environment (carrier, land-based, destroyer, etc.) in which the equipment will ultimately reside. It should be recognized that there is no such thing as a "universal" environment for which a boilerplate maintenance specification is applicable. This fact of life has long been recognized in the performance and functional requirements areas and much time and effort is lavished on carefully calling out performance parameters. Similar devotion and tailoring in the maintenance, support, testing and evaluation areas are needed in place of wholesale citing of boilerplate Reliability, Maintainability and ILS specifications.

Particularly conspicuous by their absence are the detailed requirements for self contained test (BIT, Diagnostic provisions, Monitoring provisions, etc.) at the detailed circuit, subassembly, or functional level. Of particular concern is the absence of a structured test requirement in the equipment specification that would cause a symmetry and agreement between functions (functional modularity), mechanical modularity, levels of replacements, and test capability. The equipment specification all too often states the test requirements thus, "the equipment shall contain BITE".

Specific parameters and test requirements are often missing from the specification structure all together. Typical test parameters which should be developed and included in future specifications are:

a. Accuracy

b. Stability (short turn)

c. Stability (day to day repeatability)

d. Scope, i.e., comprehensive ability to test all functions

e. Mode

f. Fault mode requirements

   (1) Intermittent
   (2) Combinational
   (3) Marginal
   (4) Specifications assume that faults are single occurrence, continuous, nonambiguous failures.

g. Control

h. Hardware/software test partioning

i. Test interface to next large system, i.e., control and display

j. Transitional requirements to next level of test

k. Human factors

The Support function is not considered by the Avionics specification. The specification assumes that support will be supplied at whatever depth and complexity necessary to keep the equipment operational. Requirements, guidance, constraints, or limitation that would cause the designer to make trades and critical design decisions with respect to the support system complexity, cost or effectiveness are not included. The specification requires performance only. Training, manuals and publications (page count, complexity, content), spare parts, pipeline load, etc., are not similarly included in the specification. Obviously, it is not the specification that is the offender, but rather the developers who write the specifications. The lopsidedness toward performance and away from support, test, maintenance, and life cycle values, reflects a narrow priority of design tradeoffs.

Another area in which the stated maintenance philosophy is frustraded by the specification is inclusion of nonrealistic Reliability and Maintainability requirements. The manufacturer is granted waiver in these areas and consequently tends to regard them lightly. Maintenance philosophies have often been inappropriately derived from unrealistic reliability and maintainability goals established during concept formulation. Typically, unrealistic MTBF and MTTR "goals" are specified, resulting in a DOD/Navy lock-in on the high inherent availability and

operational availability figures specified in the OR (Operational Requirement). While being able to cite an inherent high availability goal, .98 for example, certainly helps to sell a program, the fact is, that in many cases this results in artificially high MTBF's and MTTR's which are then cited as goals and not requirements. The "excessive" cost, redundant circuitry, added weight, risk, etc., in meeting these arbitrary goals is quickly pointed out by the developer, as he seeks relief from stringent requirements.

Typically, these predetermined goals never totally materialize in contractual specifications, cannot be met, tested, or evaluated prior to deployment and, as a result, never reach the fleet user. Ultimately, the fleet maintenance philosophy must be changed from that originally intended, to one which reflects the support requirements of the actual system. Additional support equipment is now required along with increased spares and increased manpower or training because the MTBF, MTTR and hence availability "goals" were never reached.

A two phase effort is suggested for development of near term future maintenance philosophies. The output would provide a maintenance philosophy or philosophies matched to the technological advances of the next decade.

a. <u>Phase I - Current Maintenance Philosophy Evaluation</u> - Selected current systems and equipments will be evaluated in terms of the cost effectiveness of their maintenance philosophies, including the impact of their philosophies on equipment and system availability. Systems will be selected from various aircraft and correlated in terms of aircraft type, configuration status, mission essentiality and operating hour to flight hour ratio. A baseline will be established to which future Avionics Readiness Requirements and Maintenance philosophies may be modeled and compared. These comparisons will be used as an aid in establishing future requirements.

b. <u>Phase II - Advanced Avionics Maintenance Philosophies</u> - The selection and implementation of future maintenance philosophies as an integrated part of the avionics design would follow from the previous phase. The generalized maintenance philosophies which have been determined to be cost-effective would be specifically tailored to hardware development programs. This tailoring would follow the pattern outlined below:

(1) Assess the failure modes, repair modes, mechanical packaging as well as functional packaging for each technological application.

(2) Generate a Tailored Maintenance Concept at Weapon System Level.

(3) Evaluate avionics WRA/SRA fault ambiguity constraints.

(4) Develop several specific Maintenance Concepts for each subsystem.

(5) Develop a Maintenance Concept evaluation model and exercise each system and subsystem against it to determine maintenance and support cost impacts for removal/replacement actions at each Maintenance level and for each technology.

(6) Select cost effective specific maintenance concept at each level for each technological application.

(7) Develop an initial ILS avionics program plan in accordance with above Maintenance Concept.

(8) As a result of above, identify potential maintainability and ILS problems.

(9) Develop training program requirements consistent with skill level constraints.

(10) Plan and generate requirements for remaining logistic elements, including:

(a) Supply Support
(b) Transportation and Handling
(c) Technical Data
(d) Facilities
(e) Management Info
(f) Budgetary Planning Data

(11) Provide LCC prediction of system support.

(12) Provide Availability/Avionics Readiness predictions.

(13) Develop specific inputs to avionics procurement specifications.

In the implementation of the above, care should also be taken to let the advanced technology determine the maintenance philosophy. Past maintenance philosophies, even though successful should not artifically determine future maintenance philosophies.

Task Areas -

a. Evaluation of current avionics system as described in the test.

b. Development of maintenance philosophies for future application as described in the text.

c. Development of an Avionics equipment specification structure suitable for stating a detailed comprehensive and quantitative requirement for the maintenance philosophy, support, test, Maintainability and Reliability requirement.

d. Development of Maintenance philosophy factors, their interrelationships, quantification of these factors and techniques for evaluation.

e. Provide guidance and requirements as necessary to the developers of new technology device, for the inclusion of maintenance and support features at the basic technology level.

APPENDIX D

SYSTEM TRADEOFF AND DESIGN

CONTENTS

1.0 Readiness Measures and Goals - The measurements associated with Avionics Readiness goals and technology, in terms of level, quality and value are of fundamental concern to efforts described by this plan. These measurements, in quantified form, are the tools by which actual fleet readiness and associated elements may be analyzed, costed, specified, developed, evaluated and ultimately realized in practice.

Current measurements are of limited value in the predetermination of support elements and the relationship that exists between these elements. The term "Readiness" in itself has different meaning for the Operation Commander, the developer, the supplier, the support activities and various Washington managers. Each has his own priority, sensitivity and understanding of the term.

There is no quantified definition of "Readiness", of its component elements, or the relationship and interdependencies of these elements generally agreed upon by the affected members of industry and DOD. Without general agreement by all parties as to the quantified measures and characteristics of Readiness and its elements, there is no sound basis for establishing Readiness goals, evaluating Readiness capability, or cost planning for support.

It would be a specific task of the Avionics Readiness Program to develop a set of quantified measures relating to Readiness, its associated elements, and their interdependencies. Such measures would be employed at all levels of development, acquisition, operation and support and would be the basis for weapons systems planning, support evaluation and readiness improvement.

As part of this planning effort, the Systems Cost Effectiveness Flow Diagram, appendix D, figure 1, was developed. The diagram

illustrates the elements, inter-relationships and processes that determine the Cost Effectiveness of a system. The six shaded blocks represent areas of design and design tradeoff. On the left, they are constrained by Requirements; on the right, by Effectiveness and Cost. The heavy line that connects the Cost Effectiveness block to the System Design block indicates that the entire process is iterative and can be exercised until satisfactory balance is achieved throughout the whole structure.

The structure of the diagram requires that all areas of design be simultaneously executed. A common practice for current weapons systems developments is the design and development of the performance oriented block(s) and an "after the fact" design and development of the support blocks. A disconnected design effort predictably cannot result in a cost effective system.

The diagram shows relationships between design efforts and cost, and is applicable to whole weapon systems, avionic systems, support systems, black boxes, or any application where design is constrained by predetermined Effectiveness and Cost requirements and goals. Design to Cost and/or Life Cycle Cost goals can be assigned to each of the cost blocks. The Avionics Readiness Program will be limited to those elements in the dotted feedback loop; Reliability, Maintainability, Support, Availability (Avionics Readiness) and Support Cost (Maintenance).

In the development of the diagram, difficulty was encountered in assigning to each block parameters that can be quantified, whose inter-relationships can be numerically determined and directly compared. It is in this area that work needs to be done.

Task Areas -

a. Development of rationale and methods whereby meaningful and achievable cost and readiness goals can be established.

b. Development of parameters, measures, and interdependencies of the readiness related elements, including measurement techniques.

c. Development of Evaluation Criteria for Readiness related elements.

d. Continued Development of Cost Effectiveness model(s).

e. Development of applications of Readiness goals to the Avionics Development and Acquisitive process.

2.0 Avionics Testing - The testing of avionic systems, subsystems, assemblies, and subassemblies to ensure Avionic Readiness or restore avionics equipment to an RFI (Ready For Installation) condition has taken on many forms in the past, from manual "hot bench" mock-up techniques to the current automated test techniques. Although these techniques vary widely in methodology, each proliferates common, unrecognized, and therefore, unanswered problems, and in some cases adds new problems not previously encountered. Many of these problems can be attributed to a basic flaw in the test development cycle; autonomous test methodology. Testing at each maintenance level (factory, depot, intermediate, and organizational level) is developed on an individual basis and, in general, without regard to test routines previously developed for other maintenance levels, or those test requirements designated for future development. Test programs developed under this autonomous methodology produce test routines, parameters, and tolerances which are completely unrelated. Tests conducted at one level are not included at the next level of testing.

Procedures include tests which are completely unrelated to operational requirements. Parameter tolerances at each level of test are not structured to include all variables affecting these tests and do not satisfy the typical tolerances cone (appendix D, figure 2). The effects of these problems manifest themselves in many ways adding cost and equipment availability impacts to the Navy's logistics problems; e.g.,

a. Cyclic Rejection - Equipment is rejected at one maintenance level, and found acceptable at the next higher level of maintenance. It is returned to the rejecting level with no corrective action taken, only to be rejected again.

b. False Failure Indication operationally acceptable equipment fails test at higher maintenance levels and unnecessary repairs are made.

Current Navy and suppliers' equipment specifications do not address the autonomous test methodology problem. Current Requirements and Quality Assurance Provisions may unknowingly be the cause of this problem because they do not require continuity of test from Design Approval through Organizational Level.

Test programs are generally developed in the following order:

	Test	Development Activity
a.	Design Approval	Hardware Design
b.	Factory Production	Production Engineering
c.	Rate Testing, Weapon Prime	Quality Assurance
d.	Organizational Level	Systems Integration
e.	Intermediate Level	ATS Engineering
f.	Depot Level	ATS Engineering

Although the end objective of each test routine may be slightly different, the continuity of test from one level to another must be established and maintained to ensure the level of Avionic Readiness required to meet the challenges of the 1980 - 2000 era. Not only must the test continuity be maintained but a tolerance structure, appendix D, figure 3, must be established during hardware design.

Test documentation associated with each level of testing is poorly defined or undefined, and left to the individual judgement of test designers. Once the documentation is developed for design approval testing, there is no evidence that it is passed on to lower levels. Each test development level establishes its own requirement and develops its own data. The basic test documentation and test flow need to be developed only once. All iterations, thereafter, will require changes to parameter tolerances only. The nominal value of each parameter and the order in which they are tested should remain the same.

Avionic support planning must take place during the early stages of development for all avionics end items if Avionics Readiness is to be achieved. Each of the following matrix elements should be considered in the support planning phase:

a. Operational Sites
b. Avionics Equipment
c. Hardware-Software Technology
d. Test Methods
e. Applications
f. Repair Level
g. Test Technology
h. Avionics Hardware Failure Modes

i. Test Mechanization

j. Test Parameters

k. Test System Support

l. Test System Requirement and Deficiencies

m. New Development to Satisfy Deficiencies

Under each of these items a host of detailed elements can be identified, defined and organized into an effective plan.

It shall be a specific task of the Avionics Readiness Program to develop an integrated systems test plan which insures effective testing at all maintenance levels, reduces support personnel and associated skills requirements, and provides useful test design documentation early in the program for use by all test development organizations.

Task Areas -

a. Development of a test design which includes tolerance cone considerations, microprogramming techniques, establishes realistic ambiguity objectives and allows for early demonstration and utilization of all support elements.

b. Development of data standards which will satisfy test requirements for all levels of testing.

c. Development of standard test techniques for commonly used circuitry.

d. Development of standard test demonstration plans which provide for fault insertion in all diagnostic test program demonstrations.

e. Develop a detailed avionics test matrix as a design tool.

3.0 Weapons Systems Support - The testing of avionics weapon systems to insure Operational Readiness and verify repair at the organizational level is accomplished in many ways including subsystem carry-on-SSE and BIT (Built-In-Test). Each of these methods, or combinations thereof, are used to establish a level of confidence in the avionic equipment's ability to satisfy its mission objectives prior to the start of the mission. It is also used after the completion of a mission to determine whether the avionics is still operational or if it had developed a fault during the mission. If the latter is the case, repair is effected and the test rerun to verify Repair Action Complete.

During the critical parts of the mission little is known about the condition of the avionics equipment unless a catastrophic failure is visible to the operator or is detected by IFPM (In-Flight Performance Monitor). Degraded equipment modes generally go undetected or, when BIT is used, are reported as subsystem failures, which results in the subsystem being declared nonoperational. There is no attempt to determine the level of degradation or whether the equipment is still capable of satisfying the objectives of the planned mission. Typically this mission would be aborted unless a secondary system could supply the desired mission function. Although technology is available, the priorities of system design to date have not allowed the full potential of BIT and IFPM to be included in the Weapon System. The basic Avionics Readiness and support philosophy must address this problem.

The IFPM capability for the years 1980 - 2000 will be expanded to not only evaluate the subsystem readiness condition but also, when a failure occurs, will determine function or functions affected and to what degree they are affected (appendix D, figure 4). This will reduce the number of aborted missions and give greater confidence in the ability of the weapons system to satisfy mission objectives. Additionally, it will allow the aircrew to obtain better utilization of the remaining resources of the avionics system.

The continuity of testing between and within all levels of maintenance and support will provide a more cost effective structure for weapons system maintenance.

At the organizational maintenance level, testing will be required for two basic applications, IFPM and SRT (Systems Readiness Test). As previously stated, the IFPM is designed for in-flight performance evaluation, fault detection and degraded mode evaluation to Subsystem and Subsystem Function Levels. The same basic concept can be carried into the SRT application, with two additions; fault isolation is expanded to the WRA (Weapons Replaceable Assembly) and calibration tests for those functions requiring periodic calibration. (Calibration in this context refers to measurement only.) Alignments and adjustments, when required to correct calibration deficiencies, should be made at the IMA (Intermediate Maintenance Activity). The SRT program is intended to provide operation readiness verification of the avionics system prior to aircraft launch and after repair and, as such, will be an extension of the IFPM.

Both IFPM and SRT should be developed from common test design data and source documentation. The continuity between the organizational and intermediate maintenance activities can be established in future support systems by requiring all tests and test philosophies applied at organizational level be included at the intermediate level. The IMA test requirements are more extensive in that they must fault isolate to the SRA (Shop Replaceable Assembly) and component levels of repair. Therefore, additional fault isolation routines must be included in each test program. The calibration routines at the IMA must be expanded to include corrective action routines when parameters are found to be outside desired limits. In addition, all parameter limits and tolerances established for the organizational level will be redefined to allow for tolerance buildup as shown in appendix D, figure 3, thus reducing the cyclic rejection rate.

The requirement for Depot level testing should include those test programs, with tolerance consideration as shown in appendix D, figure 3, generated to support the IMA and special programs as necessary.

Once again factory testing can contain the same routines and procedures as used at the IMA and Depot, except the degraded mode routines would be deleted and parameter limits and tolerances changed.

Test routines established at one level of testing and carried through all other levels of testing can reduce the cost of test development, minimize cyclic rejection, and false failure repair.

The foregoing has described in very general terms the basic test philosophy proposed for the Avionic Readiness Program. Before effective implementation can be achieved many associated elements must be examined and evaluated. Appendix D, figure 5 is a graphic presentation of each of the elements to be considered.

The commonality of requirements shown in appendix D, figure 5 provides an example of the commonality which can be provided with an integrated approach to support.

Task Areas -

a. Develop an overall Weapons Systems Support Matrix, which includes as a minimum, establishment of a support posture (hardware and software) for organizational and IMA levels of maintenance and associated specification requirements.

b. Standardize software interfaces and routines at ORG and IMA levels of test and implement micro-programming techniques wherever possible.

c. Determine test requirmeents for each level of test these will include but not be limited to:

(1) Range
(2) Accuracy
(3) Granularity
(4) Resolution
(5) Repeatability
(6) Stability (short term)
(7) Stability (long term)
(8) Reliability
(9) Threshold
(10) Sensitivity

d. Develop fault detection and isolation techniques for the following failure modes:

(1) Multiple hard failures
(2) Single soft failures
(3) Multiple soft failures
(4) Intermittent failures
(5) Non-symptomatic failures
(6) Indirect failures

e. Assist in the development of subsystem functional packaging requirements and location, selection, and standardization of BIT on each subsystem for fault isolation to the subsystem function and degraded mode evaluation as indicated by the Weapons Systems Matrix.

4.0 Standards and Commonality - The issues of standard equipment and commonality across weapons systems is vital to avionics readiness. What equipment is standard and where commonality is applied has a major impact on production, training, and support costs of an avionics suite for a weapons system.

The most frequent definition of standardized avionics is the use of equipment of the same design over a large number of aircraft. This approach, with its associated hazards of standardizing on a bad design and being inflexible to technology changes and improvements, does not appear realistic in light of the modern pace of technology and consumer driven electronics development. A new standardization concept that allows frequent modifications and updates to the basic technology must be developed. Various studies,[1,4] initiated by DOD, have come to this same conclusion, and have recommended the adoption of a form, fit, and function standardization concept. Using this method, only the physical attributes, interface requirements, and performance of a unit would be specified, and the internal design, technology, and general implementation would be left to the contractor. Competition could be maintained throughout production, with its resultant cost benefits.

This concept, however, does not adequately address support costs. A technology or design change in a piece of equipment may improve or leave unchanged its performance characteristics, but it will almost always change its test characteristics and response to failure conditions. This will require reprogramming of any support software (i.e., VAST Test Program Set), resulting in a larger cost than first estimated.

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4 Economic Feasibility of Standardized Avionics, Task 73-12
May 1974, Logistics Management Institute, DID Contract SD-321.

This problem can be eliminated or reduced by two methods. Either a long term warranty is procured with the equipment, and service is performed at the manufacturers plant, or Built-In-Test is originally specified for the equipment, with a fixed test and maintenance interface.

A recent study[1] has indicated that standardization must be considered on a case by case basis. The conclusion was that system complexity was the determining factor. As an example, it was more cost effective to standardize an inertial navigation system for four aircraft platforms than to standardize a radar altimeter whose total procurement would be in the hundreds.

It therefore appears that there is a cutoff point below which standardization is not profitable, and that this point depends on the unit itself, as well as the number of units to be procured.

It is necessary, then, to develop a procurement procedure that takes into consideration the following standardization/commonality tradeoff factors:

a. The (near) optimum level of standardization.

b. The specificaion of that level according to form, fit and function.

c. The specification of a maintainability interface below that level, such that changes in manufacturer or technology will have a minimal impact on support hardware and software.

d. The procurement of a long term warranty on the equipment. (It should be noted that the warranty need not be bought from the end item supplier.)

The tradeoffs involved in this process must depend on the estimates of Life-Cycle Costs for the equipment. If the recommendations outlined in the DOD "Electronics-X" study are implemented, the techniques of life cycle costing will become much more manageable and accurate, allowing tradeoffs like those above to be made with a reasonable degree of confidence.

Task Area -

Under this section would be the development of a life cycle cost model that takes into account the cost tradeoffs involved in standardization, ATE compatibility, and form, fit, and function specifications. The development could involve the modification of an existing model. (Reference appendix F.)

5.0 System Architecture - Most of the recent weapon systems introduced into the fleet use digital system technology extensively. These systems have been developed to perform complex functions in a wide range of military environments where high performance is required. The digital systems process, with hardware and software, all types of information to perform tactical, navigation, communication, and command and control functions. Most of the system's implementation emphasis has been in the grouping of the major aircraft's subsystems to a central computer. This approach has kept the cost of the system's hardware down, at a time when special purpose subsystem processors were large and costly, prohibiting any federated computer systems architecture that would incur added computer costs. The uniprocessor approach has throughout the years escalated the cost of software development with the increase in demand for totally integrated, high performance, complex weapon systems. The use of the conventional hardware approach and the software implementation of complex algorithms have caused a wide unbalance of hardware/software/support costs that could be reduced by the introduction and availability of the LSI (Large-Scale-Integration) technology. The LSI technology is rapidly becoming available as a standard line at a relatively low cost.

A system design definition that can measure the size and depth of the allocation of the hardware, software, support, and operational characteristics related to costs, should be made very early in the program. Reallocation of these parameters should be exercised to reduce costs, as an iterative process, until an optimum balance is achieved. This process can be exercised by constructing a problem model that illustrates the impact of each of the systems characteristics, with computer aided design where applicable. If any of these areas remain as fixed parameters at prohibitive costs or have a large technical risk, it should force further analysis of the adequacy of the performance and support specifications. A federated processing architecture tailored to individual functions will lend itself to a flexible application of the aforementioned design model.

The federated system approach can be extended to all levels of data processing covering standard computers, minicomputers, and microprocessors. The number and type of processors and level of federation utilized is determined by the nature and depth of the functions as defined in the subsequent paragraphs:

a. Minicomputers - The minicomputer should be the highest level of federated processing to perform system functions and microprocessor integration and control.

b. Microprocessors - The microprocessor circuits should be used to perform dedicated functions, complex algorithms, complex interfaces and dedicated peripheral control.

c. Standard Computers - Large scale computers should only be used for higher level data management and extremely complex data processing computations. Computers of this class should be used only when they are readily available.

Since a number of processor combinations are available, a federated system architecture as described above allows the system designer to make key design decisions and tradeoffs, on a life cycle cost basis, with much greater ease and flexibility than with centralized systems. Some of the new options open to the designer are categorized below:

a. Hardware/Software Functions - Assigning particular system functions to individual processors simplifies software overhead and reduces software costs. Such tradeoffs can be made to produce optimal cost-effectiveness.

b. Hardware/Software Failure Recovery - Failure recovery or degraded mode operation can be accomplished by fully redundant hardware, partially redundant hardware (i.e., one backup "mini" for the whole federated system), or software routines. The proper combination can be more easily achieved in a federated system.

c. Growth Potential - Since a federated system provides relatively inexpensive updating, evaluations can be made trading off specification of growth potential (overcapability) with the cost of a later update.

d. Low Performance/High Performance Hardware - A strict performance criterion may be met either with one piece of expensive equipment or several less expensive units, thereby allowing a support determined decision.

e. Commonality - Commonality benefits can be considered both within and across weapons sytems, and in both the hardware and software areas.

f. Functional Packaging - Failure recovery, fault isolation, and operating systems software are all made more simple if one function is located in one physical package. Multifunctional packaging, however, reduces acquisition cost.

Task Area -

The recommended task is the development of the avionics readiness potential of federated systems, with the objective of providing the proper systems architecture to the overall weapons system development of appendix D, section 7.

6.0 Subsystem Implementation - The major theme stressed in the previous sections is that supportability and performance should be equal factors in determining the acceptance procedures for avionics hardware. Additionally, the methodology that should be developed to properly specify the support requirements and determine the tradeoffs with performance has been stated. To prove the methodology developed, the recommended solutions must be applied in some form to a realistic situation. It is the intent of this program to select a subsystem whose design and implementation are consistent with the timing of the proposed plan, and which has a variety of functions to which advanced technologies can be effectively applied. The design and development of the selected subsystem should demonstrate, on a limited scale, the following factors:

a. The realistic application of the life cycle cost reduction methods developed in this plan.

b. The effectiveness and applicability of the readiness measures and measurement techniques generated.

c. The improvement of readiness capability using advanced technology.

d. The feasibility of generating and enforcing readiness standards and specifications.

e. The feasibility of a common test structure at all levels of maintenance.

f. An overall improvement of the readiness factors of the subsystem.

The requirement to actually develop and demonstrate Avionics Readiness and Support capability, necessitates development of representative avionics equipment or modification of existing developmental or fleet equipment. It is assumed that funding limitations will restrict the effort to the modification of existing equipment. Selection of equipment and modifications that will satisfy task objectives is critical. Criteria by which the candidate equipment will be selected includes:

a. Affordability - It is assumed work must be constrained to an existing equipment or subsystem's implementation and that the whole weapon system level is beyond the scope of the task (refer to section 7). It is further assumed that the modification and/or implementation in itself is within funding limits.

b. Evaluation - The object equipment and modification must provide measurable and meaningful results. All conclusions must be able to be related to real world problems and capabilities.

c. Spin Off - When possible, selection should favor equipment where there is a logical and rapid application to current fleet equipments that are experiencing Readiness and Support problems of an urgent nature.

d. Availability - The equipment must be available on either a grant or loan basis or be small enough in cost to be affordable. The equipment must also be available for the duration of the task.

e. Technology - The selected equipment should be of a technical vintage that allows full development of concepts and capabilities developed within this program.

f. Scope of Effort - The equipment should allow opportunity to demonstrate several Readiness and Support Technologies; including, BIT (both digital and analog) packaging, commonality, tolerance cone testing, etc.

Upon selection of a subsystem, each of the tradeoffs and methodologies developed in this appendix will be particularized and applied to the subsystem development and procurement cycle. Outputs from the efforts in this plan will be correlated and used whenever possible.

Initially, readiness goals, measures, and measurement techniques will be developed relative to the subsystem function. These will be applied to current systems with the same function and to the selected system as it presently stands. This will provide a control to measure eventual results.

A test matrix will be developed for the selected system, employing commonality of test at all maintenance levels. A specific tolerance cone will be developed for all testable units of the system. Test program set documentation and structure will be specified. Maintenance testing will be integrated with IFPM and SRT requirements within the targeted weapons system. An integrated, common test data base, useful at all levels of support, will be developed for the subsystem.

Commonality tradeoffs, on a life cycle cost basis, will be made both within the subsystem and across all potential user weapons systems. Common circuits, modules, and black boxes will be used when justified by the above analysis. In this area, generally available commercial equipment will be considered, and tradeoffs against performance made.

The systems architecture of the selected subsystem shall be determined with equal emphasis on performance and support. Outputs available from the efforts of the federated system study of appendix D, section 5.0 will be applied. Every attempt will be made to keep the architecture flexible, in order that improved readiness measurement criteria and techniques may be applied throughout the development cycle.

A brief review was conducted of projects under development and planned for implementation in the future. These projects can be listed generically such as ASW, AAW, ESM, or generally, such as CNI, electro-optics, etc. These programs represent the full range of avionics weapons systems as well as primary flight support systems. Specifically, some of the programs are PROTEUS, MAD, AADC, ALQ-78 Improvement Program, ORICS and AIMIS. A more in-depth review is necessary to select the particular subsystem(s) which would provide the best opportunity in terms of technological variety, complexity, cost, manpower requirements, etc.

As a preliminary example, AIMIS (Advanced Integrated Modular Instrumentation System) offers certain opportunities. AIMIS covers a wide range of digital, analog, software and optics technologies. Additionally, AIMIS has completed a preliminary design and demonstration phase under 6.2 funding and is about to proceed to the ADM phase. Additionally, the system offers the potential of implemeting its concepts into the VFAX Program. Therefore, there is the logical progression from the subsystem

to the system level. Opportunities may also exist in current fleet subsystems, such as may be found on S-3A, F-14A and E-2C aircraft.

Task Areas -

a. Development of the demonstration plan.

b. Selecton of equipments to be modified and development of the modification(s). This effort shall include laboratory development and fabrication as well as contractual items.

c. The execution and evaluation of the demonstration.

d. Documentation of all Specifications, Designs, and Study Models to the extent that they can impact systems currently in development or production, if the Navy so chooses.

7.0 Weapons System Design - The Weapons System Design efforts will consist of life cycle cost driven functional design of a complete suite of Weapon System Avionics and all related support elements. Funding necessarily limits this effort to a paper design. No actual hardware or software developments will accrue to this effort; however, all hardware and software elements and functions will be considered. The Avionics Readiness Program is extremely broad and runs the risk of treating each of its many subjects in independent and isolated approaches. The coordinated Weapons System Design effort will serve as a focal point for the entire program and provide for the integration of all program tasks.

The Systems Design effort will select an advanced Navy Weapon System(s) as a model and develop the avionics systems architecture, systems maintenance philosophy, functional partitioning of hardware, functional modularity, on-board aircraft test system, test programs structure packaging and access,

degraded modes and test and repair procedures. Each avionic application; COMM, Radar, Data Processing, etc., will be provided the most cost effective test capability at organizational level for the technology involved.

The system design will be implemented at a functional level as opposed to detailed circuit level. Where, however, unique test features are to be incorporated, detailed circuit design developed in the technology applications of this program (reference appendix C) will be included.

Areas of commonality will be determined and exploited.

Reasonable limits in weight, volume, form factor, and power will be assigned to each of the operational functions. The "penalty" of incorporating self-contained test features will be indicated as a percentage of departure from these limits.

Functional requirements, designs, operating and control mode descriptions, interface, sizing through-put estimates, and the operating system structure will be developed for each application of the weapon system.

In addition to the avionic system, a complete support system at all maintenance levels will be designed. This system will include test sets, both special and general purpose ATE, diagnostic program requirements, manual requirements, spares requirements, etc. Where ATE or SSE is recommended, selection of existing capability will receive first consideration.

The design of both avionic system and support system will be coordinated. Trades will be made which will consider the effectiveness of the support as well as the performance of the system.

The common denominator for both avionics design and support design will be a target dollar value. The efforts will seek a best solution for, and combination of, performance and support within the target dollar value.

Task Areas -

a. A complete weapons system design, including performance, readiness, support, and cost tradeoffs, and appropriate documentation.

b. A complete support system design, including testers, manuals, procedures, and software functions for each level of maintenance.

c. A documented maintenance philosophy for each avionic subsystem.

The results of this effort are directly applicable to the development and acquisition of the actual weapons system.

8.0 Human Factors

Maintenance Training - Recent studies have indicated that the present method of training military personnel in maintenance techniques is too costly and too detailed[1]. Ineffective cost is the result of two factors; (1) the initial cost of training and (2) the high attrition (discharge) rate of trained personnel resulting in loss of the initial investment. The present method of training basic electronic theory effects the cost due to the details of the training and the time required to adequately educate the individual. Both cost and details can be reduced through initiating the training cycle by teaching functional maintenance on specific equipments. This approach can be expected to result in more productivity in the initial enlistments at a relatively low investment. Continued advanced training in electronic theory and engineering practices

can be offered as an incentive to re-enlistments thereby assisting in retaining a higher caliber of personnel and providing the continuity required to maintain a higher level of Avionics Readiness.

Skill Levels - One of the anticipated advantages of automatic test sets is the lower skill levels required to maintain the avionics. A recent field investigation has indicated that the number of military personnel required to maintain the avionics at the IMA has been reduced but the skill level required is greater than before. The prime reason for this is the operator must be capable of interpreting the results of the tests when ATE is inconclusive. Therefore, he must be capable of understanding not only the UUT (Unit Under Test) but also the automatic test set. Inability to interpret the test results or to affect the test parameters leads to frustration and demoralization.

Opportunities - There are several approaches which can be investigated to obtain insight in the human factors problems:

a. Functional Training - As recommended by Electronics-X, a new approach to training fresh personnel should be taken on a selective basis. This approach is to train personnel on a functional level of the equipment using JPA's (Job Performance Aides).

b. Training Methods - Support should be solicited from the academic communities to assist in developing training programs at the anticipated education level of the future enlistee as well as to develop programs which generate a logical progression of training and development for capable personnel who pursue a military career.

c. Man-Machine Interface - Consistent with the above approach, efforts should be expended to determine the physchological affects on personnel exposed to a highly sophisticated and automated test system.

The objective of this is to determine the limits of endurance of the individual and the requirements for diagnostics at various support levels. Potential cost savings in software and hardware design may be realized by allowing the individual to control the test sequence, operation or fault isolation. In short, to allow the individual to direct and control the situation vice attempting to transfer that capability to the machine.

d. Technological Support - Complementing and supporting the efforts in new training techniques and based on a more scientific approach to the man-machine interface, will be the development of techniques in functional design, packaging and maintainability through all levels for supportability, testability, and development of hardware-software/human interface. The use of self-test and fault isolation to a functional level is envisioned with advanced state-of-the-art techniques in component design and subsystem development. Continuity in software fault location and diagnostics through IFPM (In Flight Performance Monitor), O-Level, I-Level and Depot/Factory testing can result in developing logical, sequential and realistic methods of providing for the human factor input to development of diagnostic routines.

Task Areas -

a. Development of new training techniques at the functional level consistent with the planned design approaches of the subsystems selected for implementation of the advanced technology. The aid of the academic community will be enlisted to assist in this development and the development of new teaching techniques for the future.

b. Human factors engineering as applied to the man-machine interface and associated with maintenance techniques and problems consistent with the teaching techniques will be pursued. The emphasis

will be on designing the machine to work for the man vice the man work for the machine.

c. Development of a logical progression of fault isolation beginning with the system level and ending at the SRA level through application of functional packaging and packaging techniques with the limitations of advanced technology. The goals will be to minimize replacement of WRA's without cause (reduced false fault indication), to minimize the efforts of replacing of WRA's, and to minimize fault location, isolation and replacement techniques at the SRA level. Ideally, the goal would be to reduce the I-Level effort to zero and retain only the O-Level and Depot/Factory levels.

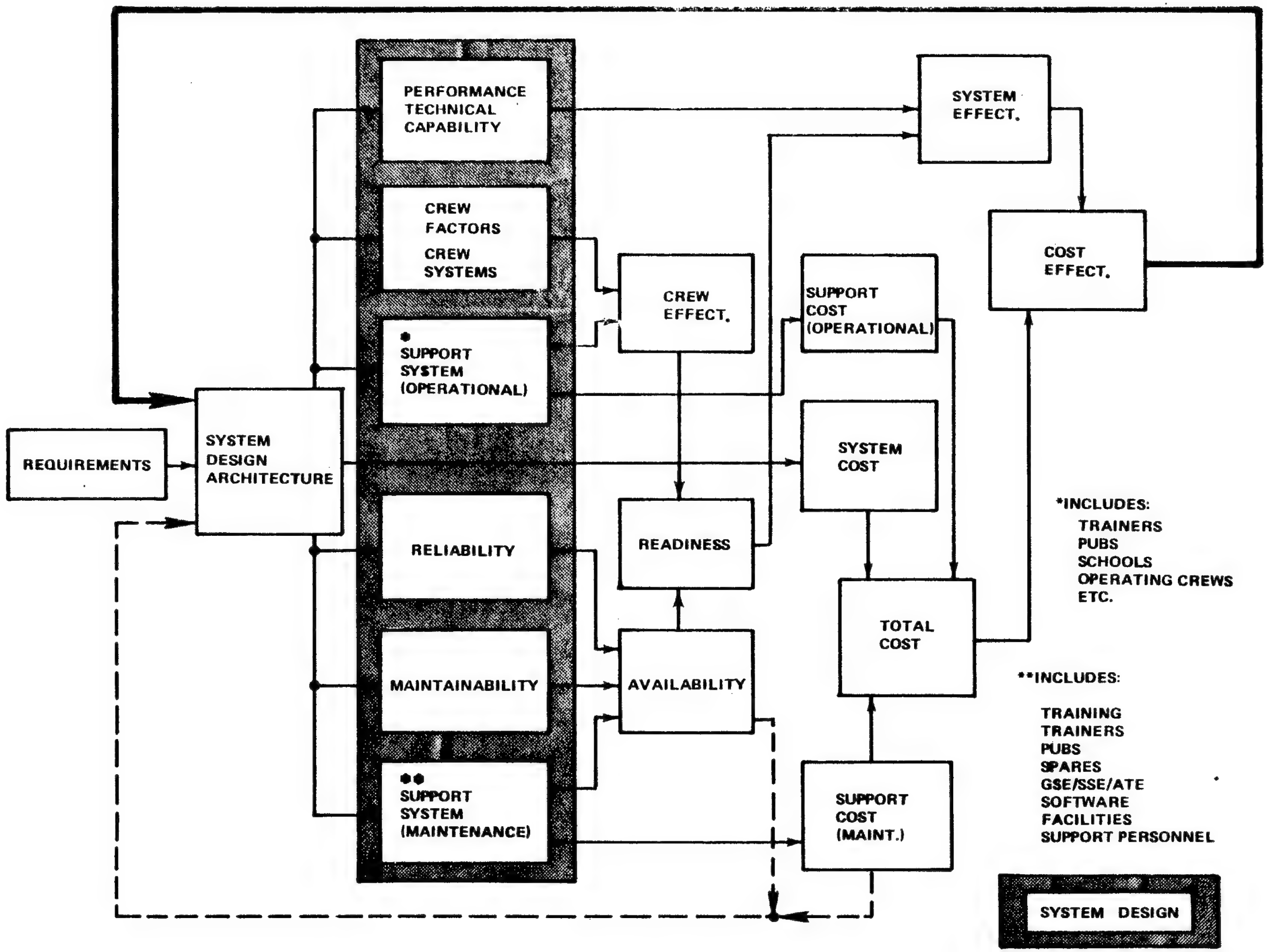

Fig. 1 System Cost Effectiveness Model

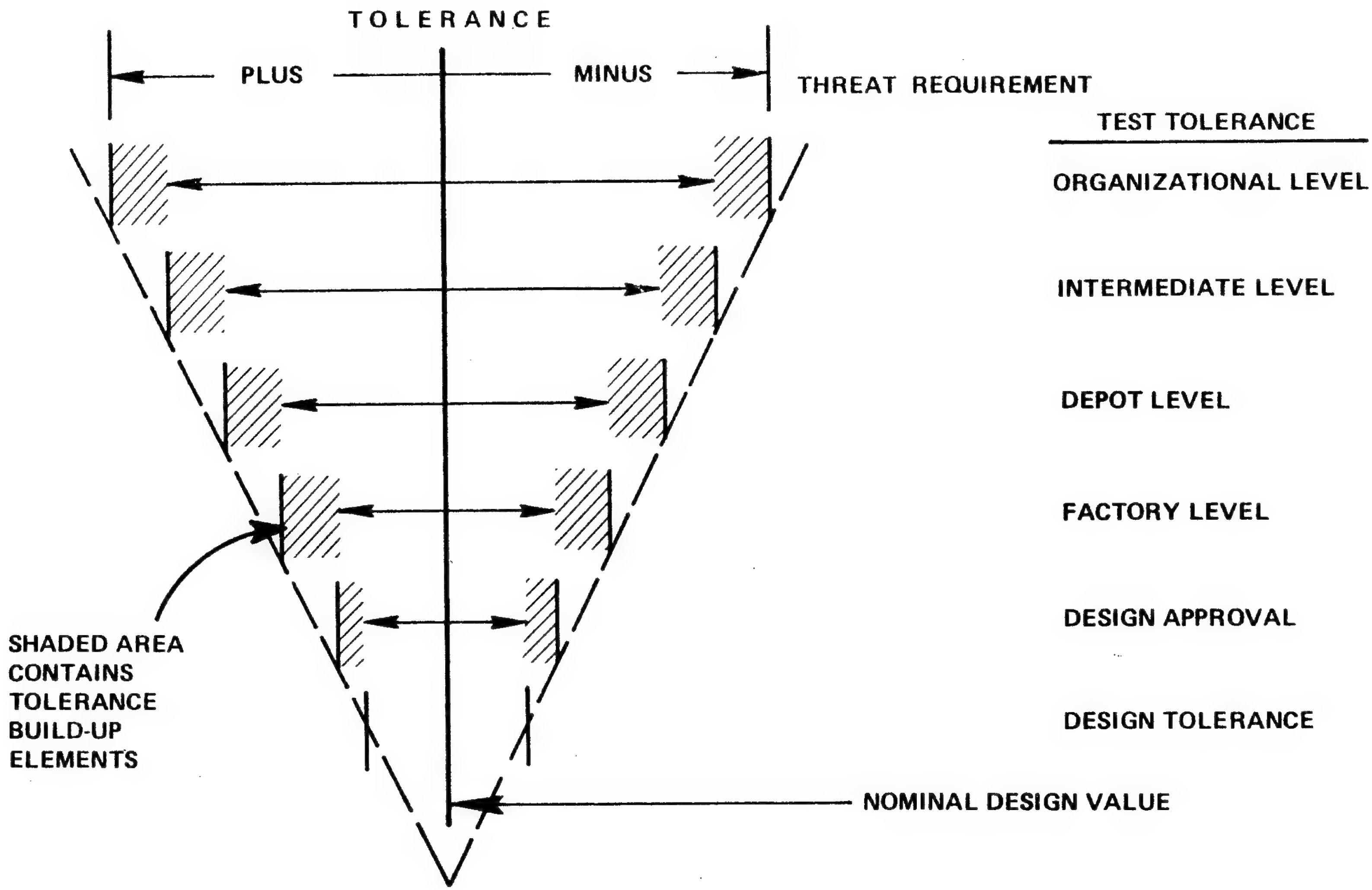

Fig. 2 Test Tolerance Cone

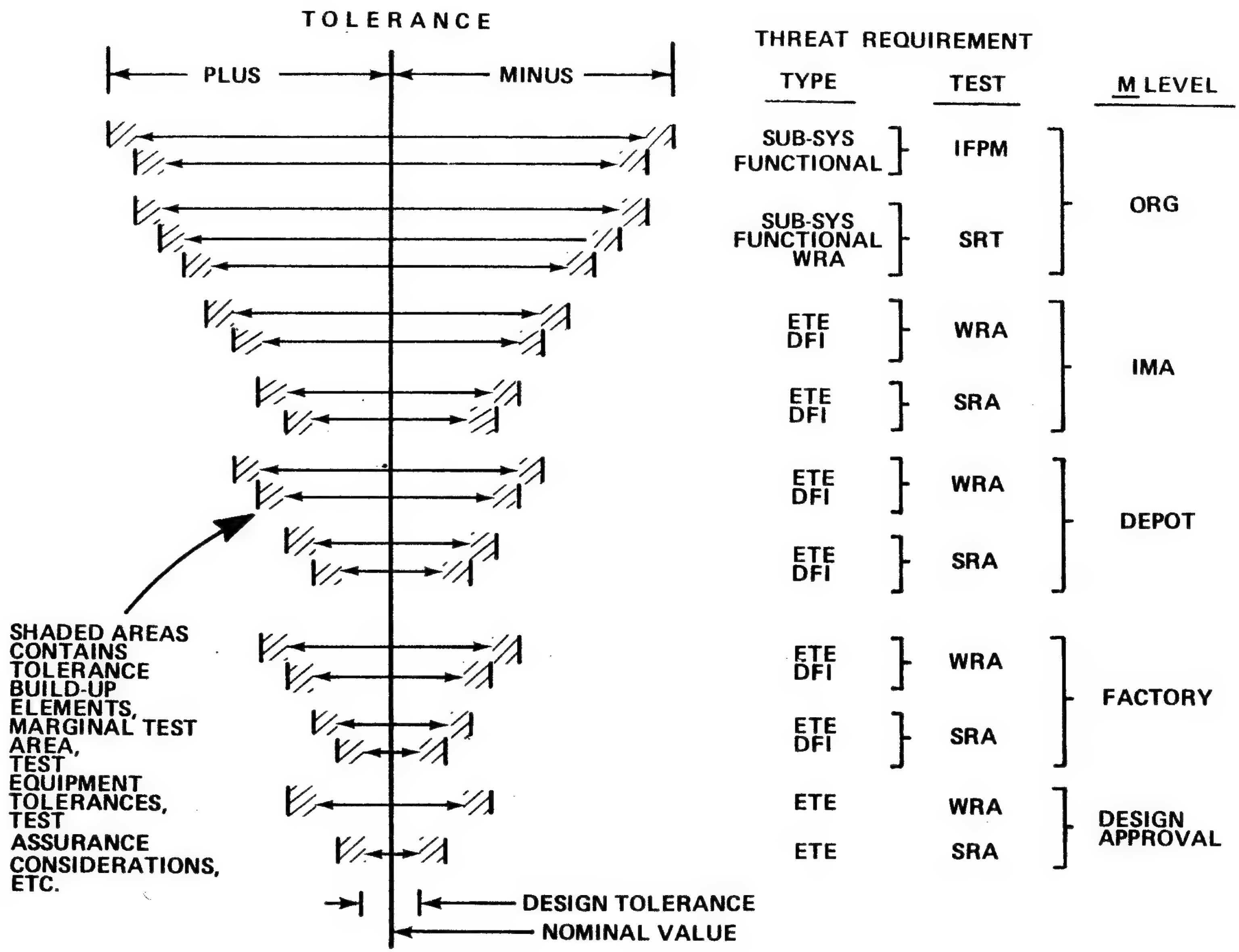

Fig. 3 Tolerance Cone Implementation

PLANNED (1980-2000)

DEVICES	ACTIVITIES	METHOD	APPLICATION	LEVEL
	• ORG.	BITE*	IFPM*	• SUB-SYS. • FUNCTION • DEGRADED MOD. *
		BITE	SRT*	SUB-SYS. • WRA • FUNCTION • DEGRADED MOD • CALIBRATION
• ANALOG • DIGITAL • RF • HYBRID	• IMA DEPOT	• ATE*	• TPS*	• WRA • DEGRADED MOD • SRA • COMPONENT • CALIBRATION
	• FACTORY	• SSE* • GSE* • ATE*	• TPS* • MANUAL • MANUAL	• SUB-SYS • WRA • SRA • COMPONENT
	• INTEGRATION	• GSE • ATE	• TPS*	• FUNCTION • SUB-SYSTEM

*SOFTWARE

FIGURE 4. WEAPON SYSTEM SUPPORT MATRIX

Level of Application / Support Element	SOFTWARE: Performance Test	SOFTWARE: Readiness Test (Functional)	SOFTWARE: Diagnostic Test	SOFTWARE: Calibration & Special Tests	SOFTWARE: Operating Systems	SOFTWARE: Generation & Debug	SOFTWARE: Simulation & Models	TEST EQUIPMENT: GSE	TEST EQUIPMENT: SSE	TEST EQUIPMENT: BITE	TEST EQUIPMENT: ATE	TEST EQUIPMENT: Computers & Data Processes	DOCUMENTATION: Source Documents	DOCUMENTATION: Maintenance Manuals	DOCUMENTATION: Procedures	DOCUMENTATION: ECP'S	DOCUMENTATION: Configuration Control	TRAINING: Trainees	TRAINING: Training	TRAINING: O.J.T.	TRAINING: Development	TRAINING: Spares
1 Factory Accep. Test (FAT)	R		R	R	PR	PR		PR	PR	R	PR	PR	R	R	R	R	R		R	R	R	R
Integration	R	R		PR	R	PR	PR	R		R	R	R	R		R	PR	R		R	R	R	R
O Level (Readiness)	R	R			R	R	R	PR	PR	R		R	R	R	R	R	R	R	R	R	R	R
O Level (Fault Location)			R	PR	R	R	R			R		R	R	R	R	R	R		R	R	R	R
I Level (WRA)	R	R	R	PR	R	R				R	R	R	R	R	R	R	R	R	R	R	R	R
I Level (SRA)	R		R	PR	R	R				PR	R	R	R	R	R	R	R	R	R	R	R	R
Depot Repair	R		R	PR	R	R				R	R	R	R	PR	R	R	R		R	R	R	R
Factory Repair	R		R	PR	PR	PR		PR	PR	R	PR	PR	R	PR	R	R	R		R	R	R	R
Weapon System Acceptance	R	R			R	R			PR			R	R		R	R	R		R	R	R	R

Tolerance Cone Adjustment

R - REQUIREMENT   PR - POSSIBLE REQUIREMENTS   BLANK - NO REQUIREMENTS

FIGURE 5. SUPPORT ELEMENTS APPLICATION MATRIX

APPENDIX E

SPECIFICATION AND PROCUREMENT

CONTENTS

1.0 Specification Inadequacies - There is reasonable cause for concern for cost effectiveness relative to Avionics Readiness. Development and acquisition costs for modern Avionic systems is high. The cost of developing, acquiring and sustaining their required support may be even higher. One could rationalize that these costs are a necessary part of owning and operating state-of-the art Weapons systems, except that, the readiness of these systems is far below what one would expect for the dollar invested.

Usually the Navy receives a fair response on the part of Industry, in providing the performance and operational capability required. The current Avionic specifications however, leave much to be desired in terms of qualitative and quantitative descriptions of Avionics Readiness, Support, Test, Maintenance Philosophy, Maintainability, Reliability, Repair, and Packaging. Small wonder delivered systems are not all one could want in the way of maintenance and support. The avionics prime item is not required to incorporate more than "general" provisions for the "ilities". The requirements are stated in generalities, and the product is delivered to that requirement.

Specifications for ADM (Advanced Development Models) and feasibility model avionics are often left deliberately vague in order to allow maximum freedom for experimentation and problem solution on the part of the developer. Even here, however, the requirement for life cycle values ought to be stressed even though it may really be too early to be specific. The tragedy of the situation is that through subsequent development stages, (EDM, prototype, limited and full production) the basic specification often fails to mature.

a. Avionics Description: The specification describes the Avionics end item, its functions, performance, controls and interfaces. The description applies to the whole of the article including operational and

support objectives. Current specification structures are out of balance, greatly favoring the operational objective with minimum space and depth allocated to the support requirement. In many cases only shallow and subjective treatment of the support subject is included.

b. Basis for Acceptance Test: The specification details discrete functions and their relationship to the overall system function. From details contained within the specification, the acceptance test is developed. Sufficient detail seldom exists with respect to the Avionics Readiness and Support function to construct a "support" acceptance test. Currently only operational parameters determine acceptance.

c. Basis for Evaluation: The detailed performance requirements establish quantitative pass/fail criteria in functional and operational areas. Support pass/fail is almost entirely subjected to externally established criteria (AR-10, MIL-STD-471, etc) as opposed to the inherent capability contained in the Avionics item itself. Again there is little quantitative basis on which to establish Avionics Readiness and Support evaluation.

d. Source Document for Related Developments: The single factor that establishes, the largest risk, and degrades Weapon(s) systems performance and capability, is lack of reliable, quantitative data in the development phases. This is particularly true when one developer must interface with another. At the functional level, where most inter-sub-systems integration takes place, the specification can do a reasonable job of providing the necessary information. However, at the maintenance test level, where exact detail is required and where many contractors may be involved, the specifications seldom supply any useful data; not even enough for planning purposes. As a result, the development of test and support system must wait the generation of another level of documentation, which unfortunately is not as authentic (precedential) as the basic specification and lags in time.

e. Object of Contract: The specification is the object of a legally binding contract, in that the supplier must develop and/or deliver Avionic end items to the terms and conditions of the specification unless otherwise modified by the contract itself. The supplier has no requirement to develop or deliver capability not required by the specification. In this regard the U.S. Navy sometimes benefits from the graces of industry, in that, we receive a more supportable product than we actually required by specification. If the desired support and readiness features are not contained in the specification at the time of initial contract, the opportunity for effective support may be lost. Where specifications are vague or indeterminant, interpretation and trades are invariably made to the suppliers advantage.

A few examples of specification deficiencies:

a. The AN/AQA-7(V), the primary acoustic processor for P-3C aircraft did not have a single authoritative specification describing its functions, performances, and interfaces for several years after its introduction. The description of the AN/AQA-7(V) was contained in:

(1) A "basic" specification
(2) A Program Technical Memorandum. (PTM) (a supplementary Hardware/Software interface document)
(3) Details of the competitive proposals
(4) Amendments to those proposals
(5) Terms of the contract
(6) ECP's submitted over a period of years

The lack of clear cut authoritative requirements, descriptions, and data in a single volume has hampered development of support systems and software for the AN/AQA-7.

b. Inference is made in Avionic specifications to VAST compatibility. Review of AR-8A, AR-9A with respect to compatibility indicates that it is a "design goal" to minimize the complexity of the ID (Interface Device) (AR-9), when the end item (UUT) meets the requirements of AR-8. Since Avionics designers are given such latitude, the result is complex and costly ID's may become a support burden in themselves. The problem here is that no details exist in the avionics specification that cause the avionics design to <u>cooperate</u> and <u>enhance</u> the VAST test objective. There are no requirements in the specifications that address the limits or constraints of support. Current documentation and guidelines for preparing specifications are antiquated. Technology has advanced at such a rate that adherence to these documents is detrimental to achieving the degree of Readiness required by the Navy today. The capability to acquire reliable, available, and maintainable weapons systems in the future is seriously jeopardized unless a concerted effort is begun immediately to correct the current specification emphasis and terminology.

The U.S. Navy must be capable of explicitly stating its requirements for support in avionics end item specifications. CNM has recently issued several "Guideline Policy for the specification of reliability and maintainability requirements in Navy contracts."[5,6] Although aimed primarily at reliability, concern is also expressed for proper <u>balance</u> between reliability and performance and to the selection of boiler plate in specifications in which is made the arbitrary selection of reliability requirements.

The efforts required to positively and successfully determine the proper specifications for reliability, availability and maintainability lie with the allocation of advanced technology to future avionics

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5 CNM Memo 09H:WW of 19 Dec 1973

6 CNM Memo 09H:WW of 18 Jan 1974

end items and the concurrent development of integral maintenance and support concepts tailored to the individual design. Supporting documentation that provides the basis for specifications must be made "open ended" to keep pace with the evolving technology.

Task Areas -

a. Development of a restructured avionics specification format, with the objective of assuring proper treatment of those Avionics features and characteristics that determine Avionic Readiness; Support requirements, test methods, test performance and quality, Maintainability, Reliability and Human Factors (maintenance) is achieved.

b. Development of Qualitative and Quantitative termonology and measures, suitable for inclusion in the format of paragraph a. above.

c. Development of an AV-XXXX requirements documents to supplement, modify or replace AV-2000.

2. Pre-Acceptance Demonstration of Test and Support - In today's environment, quantitative testing of the mean critical percentile, man-hour rate, etc., may be utilized. However, Built-In-Test parameters such as fault detection, fault isolation or allowable ambiguity are not specifically tested. These are critical parameters for a realistic evaluation of support capability. In today's environment, fault detection and fault isolation are heavily dependent upon BIT and more recently upon software diagnostics to perform this function. This has resulted in substantial projected cost savings which are derived from the deletion of the need to buy special test equipment at the Organizational level of Maintenance. However, these savings have not always materialized since many of today's BIT functions fail to detect and/or fail to

isolate to the WRA/SRA (in accordance with the proposed Maintenance Concept). Failure to demonstrate test capability prior to acceptance has allowed systems to enter the fleet with an unproven maintenance concept and with only the assumption that they can do the job. This has resulted in many costly after-the-fact changes to the maintenance concept, level of sparing, acquisition of special test equipment, etc., with a resulting burden in additional support costs and reduced operational readiness.

"Caveat Emptor"

The U.S. Navy Avionics Development and Acquisition community places emphasis on the importance of supportable avionic end items. Maintainability, Reliability, Supportability are all important words. At the time of Acceptance, however, none of these parameters are meaningfully tested. Acceptance is run on the basis of function and performance. Once these tests are satisfied the equipment is delivered and incorporated into a system (integrated). Should subsequent Reliability/Maintainability/Support features prove to be inadequate, the chances for correction are minimal, as too much time and money has already been committed to the integration of the Weapons System. Redesign to correct for Reliability or Maintainability deficiencies may jeopardize the entire Weapons System development, especially if the Avionics item is "highly integrated". Unless the article is totally unreliable the decision is invariably made to proceed and bear the brunt of the support problem. In essence, once the Avionics is accepted on the basis of function and performance, the system is committed to remain with that avionics end item, regardless of the Reliability, Maintainability or Support characteristics. Because of the involvement of integration, avionics end items are <u>virtually accepted</u> long before many of the fundamental equipment tests have been conducted.

There are some valid reasons why acceptance of Avionics end item is conducted in this fashion. This section will discuss some of these reasons and make recommendations for task areas that would provide relief in future Avionics Applications.

a. In highly integrated systems the scheduling of development and production events is paramount, in that all elements must arrive at the integration point in a narrow window of time in order to realize an efficient integration. Schedule is the driving factor.

b. Where testing or maintainability demonstration depends on a device or system external to the Avionics end item, that device or system is seldom available at the place or time of acceptance. Test devices or systems can be categorized as follows:

(1) Central Processors - Needed to run system test and diagnostics at O level. Examples are the Univac 1832 on the S-3A, and CP-901 on P-3C. Devices of this kind are always in short supply and are too expensive to be "tied up" at a manufacturer's facility for purposes of conducting Maintainability tests.

(2) VAST - The VAST test station cannot be made available at the point of manufacture of the Avionics end item since it is too scarce and too costly.

(3) SSE (Special Support Equipment) - During early phases of the Avionics development, the SSE has probably not been designed and/or assembled. It is a design impracticality for the support system to precede the Avionics; more importantly, however, funding for SSE is seldom available early in the program.

(4) Diagnostic Software - Assuming for the moment that the external Central Processor or a simulation computer is available at the time of acceptance, the diagnostic software is not. At the time of acceptance the first avionics article is the object of the acceptance. The software developers have not had the opportunity to work with the Avionics end item for purposes of program debug and verification. The inherent software lag always forces the Weapons System developer (industrial or military) to assume more risk than prudent. This is especially true in areas where diagnostic test is dependent on software.

Reliability tests are conducted much nearer in time to the Acceptance test due to their inherent independence. These tests do not require the presence of other Avionics items or support system testers. These tests are nonetheless still conducted in many cases after the fact.

There are several approaches that can be taken to insure that the Reliability, Maintainability, Support requirements are satisfactorily demonstrated prior to Avionic end item acceptance and delivery.

a. Development of a line of standard, low cost computers suitable for central or federated processor application in the Weapon system. The theory here is that these computers would be plentiful enough (because of low cost) that each manufacturer would have long term access to these computers early in the program.

The standard Avionics computer should also be considered as the standard ATE computer for the sake of commonality.

Standard computers would foster more efficient simulation, thereby providing another option for Maintainability/Support Acceptance. Additionally, operational simulation could more effectively be used at the integration site (especially with federated systems) thereby relieving the pressures of early acceptance and delivery.

). Develop a totally self-contained test capability in the ics end item, thereby eliminating the requirement for external :e: or systems.

c. Change Development schedules and funding priorities to allow :lusion of support system development concurrent with Avionics end .em developments.

d. Develop self contained test capability which is not dependent on software technologies - Presumably AAFIS (Advanced Avionics Fault Isolation System) and an analog counterpart would have application here.

e. Do not accept the Avionics end article at the manufacturer's facility or at the time of delivery, but delay acceptance and payment of profits until all requirements, both performance and support are met. Presumably, acceptance would take place at the integration facility.

f. Conduct carefully structured design reviews that cause contractor accountability for specified support and test design.

All of the above "solutions" have one or more practical real world problem associated with them. In all likelihood the more practical solutions involve a combination of the recommended solutions. However, as technology progresses, each (with the possible exception of d.) may become more practical to achieve. Correct development and application of the advanced technology can be applied with great benefit to this problem.

Task Areas -

a. Continued investigation of technologies and technology applications that allow full demonstration of Reliability, Maintainability and Support prior to acceptance.

b. Assessment of Advanced technologies to determine customer risk in support areas if avionics acceptance prior to Maintainability demonstration is a continuing requirement.

c. Determination of the best trades between, and combinations of the recommended solutions. Other solutions as they become apparent will be included.

3.0 Parameterization and Quantization of Readiness Factors - The subject of parameterizing and quantizing test and readiness factors has been discussed in the more technical portions of the plan (reference appendix C1.0, C4.0, D1.0).

This section addresses the subject primarily from a demonstration and evaluation point of view.

Established concepts in readiness and test factors have been largely analytical in nature. Although this approach fulfills a requirement, it has limitations because it does not reflect actual experience with the applicable hardware and may be beyond technological achievability or budgeting estimates.

Because the nature of the conceptual specifications for readiness and testing, implementation has been less than effective. Consequently, the accomplishment of corrective action, after equipment has been produced and fully deployed, has resulted in extensive modification efforts. Specific guidelines for determining realistic conceptual requirements are critical to accurately prescribe support parameters on which early support tradeoffs are based. Further definition is required prior to advanced development to allow refinement of the support process and to provide test accept/reject decision criteria. Data derived from this iterative process should be further refined and imposed in the contractual requirements for the full-scale development phase.

Selection of parameters for inclusion in the Avionic specification should consider the following:

a. The effect the parameter has on Avionics Readiness/Test Support capability, i.e., an importance index.

b. The degree to which the parameter can be reduced to engineering terms, i.e., numerical quantities, standard measures, discrete values as opposed to purely statistical values.

c. The ability of the parameter to be measured:

(1) Using simple test methods
(2) Using nondependent test methods
(3) With repeatability
(4) Within short time periods.

d. The relationship the parameter has to other support/test related parameters and their effect on the support equation.

e. The independency of measurement in that ambiguity does not exist between parameters for any given condition.

f. The degree of control that can be exercised over the parameter by the designer.

g. The degree that the parameter can be changed by the design process without directly changing other parameters.

h. The ease with which the parameter can be simulated.

Parameter selection and quantization should result in a set of quantities that serve the systems designer, the support analyst, the maintainability evaluators and fleet support systems planners. The parameters must ultimately be related to each other and to cost.

The Cost/Effectiveness diagram of appendix D, 1.0 requires a common denominator of measurements between certain blocks. Parameter selection should support that requirement.

It is to be expected that considerable time will pass before the Test and Support parameters included in the specification are generally accepted by industry. In fact, this may be the major problem in trying to detail test and support more precisely. Technically, it may be quite achievable, practically it may not receive acceptance. Therefore, it becomes all the more important that straightforward, easily understood concepts be developed concerning the uses and applications of these parameters.

As the cost and complexity of new avionics increases, self-contained test and low cost support features will become mandatory inclusions in all avionics. The specification, measurement and evaluation of these features will experience a proportional increase in importance. Now is not too soon to begin to develop improved approaches to the language, requirement and measures of the support related disciplines as they relate to the Avionics specification.

Task Areas

a. Categorize all support elements as they may relate to avionics design features; hardware, software, BIT, etc., and the development of a qualitative dependencies matrix for each support element and each design feature.

b. Develop an initial set of trial parameters that mutually satisfy both design and support interest.

c. Develop a design/support parameters model for purposes of determining relative importance of parameters, interrelationships, and sensitivity to change in other parts of the model.

d. Conduct seminar and training sessions between the task engineers and a wide sample of Navy enlisted and officer maintenance personnel, to the end that the task engineers are thoroughly indoctrinated in fleet procedures, priorities, limitations, capabilities and attitudes. Human factor elements would be included here.

e. Establish parameter selection criteria and develop a trial set of quantized test, readiness and support parameters. Develop the necessary tools (models, avionics hardware, and software) to determine effectiveness of the parameters.

f. Develop specification, task and evaluation criteria suitable for inclusion in the development and procurement of EDM and production avionics.

4.0 Warranties - Warranties are normally instituted where product assurances and/or supplies incentives are the issues. Some of the new technologies may add technical credance to warranty or other contractor repair programs.

The technologies of the near future and certainly those within the time frame of the Avionics Readiness Program, appear as though they will have the characteristic of reduced repairs capability at the component level by fleet activities. Avionic modules/subassemblies will contain

high functional densities, microscopic parts, several layers of wiring to interconnect logic, and critical bounding requirements at the heat sink. These features will require high skills, precise repair devices, extensive test and verification devices, programs, and techniques to effect repair at the component level. An additional characteristic of the assembly is that the components will be integrated elements uniquely configured and/or assembled at the point of manufacture and no spare parts may be available in the field either through Navy supply or commercial sources.

The characteristics above indicate drastic changes in module repair philosophies now prevalent in the fleet. On-board shop repair of modules, cannibalization, selection of nearest value replacement parts may become techniques of the past. There are strong feelings at the development community that repairs to module assemblies of these characteristics cannot be accomplished at the field level without seriously shortening the life of the assembly or worse, inducing direct catastrophic effects that will destroy the assembly. Repair should only the affected in the most controlled of facilities. Modules may become the hightest level of repair with corrective action consisting of module replacement or interchange.

Depot Repair, Factory Repair or throwaway appear to be the major options available. These options may remove the sailor from the loop except at the organizational level. Intermediate level maintenance could disappear altogether, which may be advantageous based on past experience. (There are, of course, certain equipments that will be repaired by conventional means for years to come.)

It appears that technology of the future may allow the effective application of warranty programs to Avionics repair. Warranty programs include issues such as assurance, incentives, both implied and specific,

or defect-free. Failure-free warranties, maximum failure rate guarantee, and correction of deficiencies are but a few of the warranty options available. Past procurements, however, have not incorporated adequate incentives to motivate the military avionics/electronics contractor to strive for the attainable reliability during equipment development nor has it encouraged them to achieve maximum reliability during production for the "end-item" and to sustain it after deployment. In fact, there exist counter-incentives: reliability specifications so low as to be useless or so high as to be unrealizable; rigid configuration control that inhibits salutary changes (Electronics-X, section IV-D); lucrative spare parts contracts that reward operational failures; and most important, economic pressure to minimize cost of development and production regardless of support costs.

Few program managers have imposed warranty options during the acquisition process. Present trends indicate a continuing reluctance to do so, primarily because of the initial cost impact and secondly, from the lack of adequate Life Cycle Cost justification. Several attempts have been made but typically are time limited by insufficient funding and support. Time limited warranties may pose more problems and additional costs downstream when the warranty period expires and the Navy becomes saddled with the support management effort.

Long term maintenance warranties, when applied as part of the procurement contract, suggest motivation on the part of the contractor to provide a higher degree of reliability and maintainability during product development. However, it does not suggest that the support inventory will be substantially reduced. In fact, the inventory may actually increase since the total number of support sites may increase and each equipment may require its own Peculiar Ground Support Equipment to be strategically located at the contractor's plant. Each new long-term mainteance warranty could generate the requirement for one or more additional piece of PGSE.

Task Areas

a. Assessment of advanced technology devices; their most likely assembly and manufacturing processes, their packaging constraints and the most promising repair techniques. Recommendations will be made for required training programs, skills, test and repair equipment, and facilities for repair afloat capability.

b. Review and assess spare parts availability for advanced technology components, potential sources and accessibility to the out-of-port fleet. Feasibility of ASO or commercial sparing will be determined. Where spares at the field level are an impracticability, feasibility of obtaining emergency spares by cannibalization will be considered.

c. Assessment will be made concerning requirements for factory, depot, or contractor repair as opposed to sailor repair. The result of tasks a. and b. will be combined to determine technical dependency on contracted repair.

d. Detailed review of each type of warranty and its application with primary emphasis devoted to the total life-cycle support impact. Extended fleet life must be considered for those types of equipments where extensions often occur. Equipments with extremely short life-cycles such as electronic countermeasure devices may not be appropriate for long-term maintenance warranties.

e. Comparison of warranty programs and other contractor repair and support programs that may have some natural application to the repair modes of the advanced technologies. Comparisons will be made on LCC basis.

APPENDIX F

COST ASSESSMENT

CONTENTS

1.0 Introduction - A recent assessment of on-going defense system development programs indicates that in almost every area, the estimated costs of new systems substantially exceed the ability to buy them in needed quantities. Personnel costs have risen from 42 percent of the FY 1968 DOD budget to 56 percent in FY 1973, while personnel have been reduced by 1,477,000 during the same five year period. The maintenance of defense systems is presently estimated to cost about $20 billion per year.[7] These findings, substantiated by those of numerous studies conducted during recent years, are vivid indications of the real world environment in which defense system development programs now and in the future, must be effectively managed and controlled relative to cost as well as technical performance. Out of a total DOD FY 1974 budget of $81.1 billion, electronics outlays total $15.3 billion;....RDT&E, $4.1; Production, $5.8; Support, $5.4 billion. Annual support costs for military electronics equipment are not almost equal to annual production costs, consuming more than one-third of all annual expenditures on military electronics.[1] In view of this environment, relative to fleet avionics, the Avionics Readiness Program has two objectives, both of equal importance:

a. Significant improvement of aircraft Readiness.
b. Reduction, if not the reversal, of support cost growth.

Cost analysis is a key parameter to the success of Avionics Readiness. Credible cost estimating to allow effective cost performance and cost benefit tradeoffs must be available to determine the worth of proposed solutions to the readiness problem at hand. In the current DOD environment of austere program management, cost analysis is rising in importance as a criterion for measurement

7 See generally Defense Management Journal, "Design-to-Cost, pp 2-3, Sep 1974

of a program's value. This section discusses problems associated with cost analysis as they appear in today's weapon system procurement structure and proposes paths of solution for these problems.

The section is divided into four sections, all with their own unique characteristics and problem areas, yet very much interrelated. The sections are:

1. Cost Credibility
2. Cost Targets
3. Cost Estimating Methodology
4. Shifting Cost Centers and Support Development Planning

Each subdivision provides a general discussion, detailed issues of concern and recommended task descriptions to overcome problem areas and provide support to the overall costing needs of the Avionics Readiness Plan. The tasks proposed are by no means easy but were constructed to be worthwhile and achievable. Correct program cost planning is and will continue to be a vital element in the determination of total program success.

2.0 Cost Credibility - Serious problems exist in the area of cost estimating within the Navy and more generally within DOD at the present time. Due to the history of cost overruns and discrepancies between cost/performance/ schedule on major weapons systems acquisition, a profound credibility gap has developed between the program cost analysts and various levels of review authority within the program approval chain of command. The misunderstanding of what is included in a Life Cycle Cost Estimate as compared to what is eventually spent has caused some to renounce cost estimating in general. At the present time, many cost elements of a program are hidden or unknown, and are virtually impossible to estimate in the early stages of development. Proper

definition of cost elements (especially in the support area) can be achieved, and reasonable estimating techniques developed and validated in order to improve cost profile management abilities and close the gap that exists in the cost estimating sphere.

The total system of program management, fiscal control, and cost accounting must be examined to isolate specific problem areas and recommended solution paths associated with cost credibility. Poor cost credibility is perpetuated when long-range planning cost estimates do not correlate with actual program expenditures as time progresses. However, very rarely does anyone take time to examine why cost estimates do not come to fruition. A brief examination isolates the following problems which can be considered as the prominent issues associated with current costing practices.

a. The impact of technology changes on program costs.

b. Present budgetary policies and procedures which faction what otherwise may be a unified organization.

c. Change in program schedule, direction, and/or scope, without proper ascertation of impact on program cost.

d. Hidden costs due to deficiencies in cost accounting methods.

e. Questionable validity of existing data banks upon which cost estimating techniques are generally based. (In particular, the Navy's support cost tracking has been seriously lacking from the point of view of accounting by system, aircraft type, model, series.)

These factors along with others that are uncovered as time progresses must be addressed and resolved if long-range cost estimating is to become a viable discipline within the structure of DOD. Changes in cost structure must be researched, developed, reviewed, approved and implemented within the Navy in order to provide true cost visibility to specific programs. With cost credibility, the doors are open to more rigid application of Design to Cost, Cost Targeting, and design cost/performance tradeoff principles. As confidence in cost estimates increases, the relationship between government and contractor will strengthen and more cost effective products (weapons systems and associated support systems) will be developed.

<u>Task Areas</u> - In order to arrive at a more positive weapons system cost credibility posture several tasks will be performed. These tasks are geared toward examining the situation as it exists today, isolating the most serious areas of concern and recommending solutions:

a. Survey of existing data collection systems within the Navy and DOD for adequacy relative to use for generation of cost estimating techniques (primarily for support function elements); deficiencies in data systems will be noted and possible corrective actions identified.

b. Development of a viable and effective Cost Profile Structure, in which cost elements will be defined, with emphasis on support costs, to match what is thought to be a workable structure that will allow ease of computation and tracking.

c. Examine present budgetary management and constraints relative to program planning and progression. Isolate problem areas directly attributable to budgetary policies.

d. Isolate Navy/Contractor Program Management policies that contribute to excessive cost isolative to weapon system procurement practices. The basis for this work can be derived from Lockheed-California Company Report No. LR 26080 entitled "Study of Naval Aircraft Weapon System Procurement Practices" dated 1 November 1973, performed under contract to NADC (N62269-73-C-0783).

e. Investigate the impact of program schedule changes on Life Cycle Cost of the program. Develop work-around procedures to employ when schedule changes occur that will minimize the impact on life cycle cost.

f. Summarize recommendations derived from previous five tasks to form basis for plan to increase cost credibility for use as an effective management tool.

2.0 Cost Targets - Cost targets are rapidly becoming an integral and predominant design factor within the development of weapons sytems. No longer will DOD allow the procurement of systems based on performance only; weapons systems cost must be both performance and support with respect to projected budget constraints. Methodology must develop to allow accurate allocation of monies (target costs) for both primary hardware and software as well as their associated support systems. It should be emphasized that Design-to-Cost and Target Cost Allocation are not merely procurement buzzwords but rather the directed methods of new weapon system acquisitions.

Design-to-Cost and Target Allocation should not be restricted to the Unit Production Cost of major weapon systems, but extended to cover the total spectrum of Life Cycle Cost (Development, Production, Operations). A balanced attack on all phases of Life Cycle Cost from the point of view of management control is necessary.

Annual expenditures for military avionics and their associated support are spiraling at such a rate as to cause grave concern relative to their near term affordability. Future systems must be designed to strict management controls that will ensure procurement of the most cost effective combination of primary mission equipment and companion support equipment. This is not an easy task. Methodology for new more efficient procurement practices must be developed. All nonessential performance goals must be stripped from new procurements to clear the way for economically prudent buys. Design-to-Cost as presently implemented only begins to satisfy this requirement. It lays down affordable Unit Production Cost goals (targets) for total system procurement exclusive of support. The contractor then allocates this target further down his organization to the designers and tells them their cost targets for their particular area of interest. Internal cost tradeoffs are conducted by the contractor in an attempt to make the sum of the individual cost targets equal the overall system cost target. This process is beginning to work but more scope is needed. Cost target allocation must be provided for all facets of program cost - the Life Cycle Cost.

The government, in order to provide closer control of total program costs, must be capable of allocating support as well as production cost goals. A contractor must be provided with contractual incentives and penalties geared toward producing a supportable system. Pre-agreed upon measures of system support cost must be

determined, line items of cost allocated and continually updated by government/contractor cost teams, then precisely measured during a controlled evaluation period. Incentive payments will be based on test results. Caution must be exercised to assure that the measures of system support cost are directly accountable to the contractor's design and can be objectively evaluated.

Plans and procedures along these lines have been initiated by the Air Force but much more work is needed.

Task Areas -

a. Survey recent Design-to-Cost/Cost Targeting philosophy and/or implementation studies within DOD and the determination of reasons for either the success or failure of study recommendations. This should eliminate any unnecessary duplication of effort relative to the problem of cost targeting.

b. Develop a management plan for Life Cycle Cost target allocation implementation (with specific emphasis on support cost target allocation).

c. Investigate/determine methods required to incentivize, contractually, contractor performance in meeting pre-established support cost targets.

d. Determine methodology for correlating cost targets assigned in the three principal areas of Life Cycle Cost (Research and Development, Production, and Operations).

4.0 Cost Estimating Methodology - The primary objective of all cost estimating methodology is to predict the cost of a definable element of work or material. The cost elements of work and material when compiled into a Program Work Breakdown Structure constitute a program cost estimate, usually the cost to acquire and perform a function. Although many and varied methodologies exist to estimate costs, there are many problems inherent in each which limit their usefulness and credibility.

The Navy and DOD are at present engaged in efforts to improve the state-of-the-art of cost estimating, but for the most part these efforts are long range in nature and aimed at better data collection for the future and gross parametric estimating. Although the major area of current interest is acquisition cost, efforts in Life Cycle Cost estimating improvement have started but are in their infancy and are not in a state where the methods can support detailed readiness/cost tradeoffs.

The importance of accurate and timely cost estimating cannot be overemphasized. Proper fiscal management and sound cost/effectiveness tradeoffs can be directly attributible to good cost estimating methodology.

Many current cost estimating techniques are lacking in validity, especially in the area of Navy support and operating costs. This is due primarily to the deficiency in existing cost reporting and tracking in the support area. Support costs are not easily associated with particular equipments or even with specific type, model, series aircraft due to procurement policies of Navy supply offices. Just now, breakthroughs are occurring that will soon allow the development of more valid support and operating cost estimating methodology if research money is provided.

Areas of primary cost estimating concern other than those of support and operating costs are the ones for which costs are rapidly rising and for which no validated methodology exist. In particular, the integration of software development with avionics hardware is in need of detailed cost estimating methodology.

Care must be taken in the development of any cost estimating methodology to make cost estimates dependent on meaningful parameters. Even if good correlation is found between cost and "meaningless" parameters from historical data, there is no guarantee that this correlation will apply to future weapon systems. Unless the true cost driving factors are present in cost estimating relationships the techniques are suspect and will certainly fail in time.

A unified approach to estimating cost, in particular Life Cycle Cost, must be developed within the Navy to ensure consistent program cost evaluation.

<u>Task Areas</u> -

a. Survey and research existing cost estimating methodology within DOD with special emphasis on avionics and avionics support cost line items. Investigation will include not only the assembly and listing of available cost estimating methodology but also an evaluation of each noting the pros and cons relative to possible use within the Navy costing structure. Isolate areas of gravest concern regarding deficiency or absence of existing cost estimating methodology. Prioritize these areas as to highest overall Life Cycle Cost impact on a weapon system program.

b. Acquire/develop necessary data bases to enable a complete analysis of cost driving factors associated with line items for which estimating methodology is desired.

c. Develop cost estimating methodology for highest cost impact areas where methodology is deficient. Assure that independent variables upon which costs are based are truly cost driving variables.

5.0 Shifting Cost Centers and Support Development Planning - Cost Centers will be defined to mean an accountable category of money expenditure. Under this definition, cost centers will be discussed in two contexts:

a. In terms of gross Budget Categories such as Research and Development, Procurement, Operations and Maintenance.

b. In terms of line items of a typical Contract Work Breakdown Structure, e.g., airframe, avionics, power plant and further subdivision of these major categories.

A cursory examination of current expenditures by cost centers for weapon system procurements shows how technology is changing expenditure ratios between line items of cost. The trend of former years where avionics, avionics support software, and integration costs were low compared to actual hardware costs is showing a reversal. For example, software costs for automatic test equipment for the F-14, S-3A and E-2C have spiraled beyond all expectation. In addition, much of the shifting cost center dollars must now come out of R&D where previously Procurement costs bore the major brunt of the cost of that particular function. In general, weapons system fiscal planning has not stayed abreast of rapidly changing cost centers, causing not only budgetary problems of great magnitude, but also has reduced systems readiness and capability.

The impact of shifting cost centers on future avionics readiness must be identified, analyzed and resolved in the near future to insure effective fleet operations and prudent fiscal planning. The primary issues of concern are:

a. The impact of shifting cost centers due to technology, changes upon fiscal management and credible cost estimation. The current budgetary system must accommodate deviations in dollar concentrations among cost line items in future procurements.

b. Design-to-Cost and Cost Targeting will have to be modified and integrated to take into account shifting cost centers.

Task Areas -

a. Survey existing cost centers and determine contents of each line item of cost. Determine from history general ratios of cost between related cost centers, e.g., avionics versus avionics support, avionics systems hardware versus avionics integration, etc.

b. Use advanced technology information to be compiled under a task of appendix B to project degrees of change by line item for a typical aircraft weapon system of defined complexity and performance developed for the 1980-2000 time frame. Projections of cost centers will also be shown in terms of incremental step changes for weapon systems in general.

c. Investigate and recommend prudent interfaces of Design-to-Cost and Cost Targeting with respect to results of analyses on shifting cost centers. This task will be coordinated with efforts expended under section 2 of this appendix.

APPENDIX G

AIRTASK

AIRTASK/WORK UNIT ASSIGNMENT
NAVAIR FORM 3930/1 (REV. 9-69)

DEPARTMENT OF THE NAVY
NAVAL AIR SYSTEMS COMMAND
WASHINGTON, D.C. 20360

See NAVAIR 3900.8 or supersedure for applicable details on completing this form.

CLASSIFICATION: UNCLASSIFIED

ADDRESSEE: Commander, Naval Air Development Center, Warminster, Pa. 18974	AIRTASK NO.: A3400000/001B/5F41461408 — AMEND. NO.:
	WORK UNIT NO.: N/A — AMEND. NO.:
	EFFORT LEVEL: Normal
NAVAIR PROJECT ENGINEER: Mr. B. L. Poppert — CODE: AIR-340E	CLASSIFICATION OF AT/WU: UNCLASSIFIED

1. The AIRTASK/XXXXXXXXXXXXXXXX described below is assigned in accordance with the indicated effort level and schedule. Funding authorization for AIRTASKS will be provided in separate correspondence. If this AIRTASK/XXXXXXXXXXXXXXXX cannot be accomplished as assigned, advise the Commander, Naval Air Systems Command, and the NAVAIRSYSCOM T&E COORDINATOR, if applicable. No work beyond the planning phase will be accomplished unless the addressee has funds in hand or written assurance thereof.

2. Enclosure.

(1) Program Plan Development for Avionics Readiness Improvement of 11 Oct 1974.

3. Technical Instructions.

a. Title. Avionics Readiness

b. Purpose. Assignment of effort under requirements for FY 1975.

c. Background. This Airtask covers the development of a long range plan for the improvement of Avionics Readiness in the 1980-2000 time period. The plan will include future operational requirements, an assessment of airborne and test system technology and related logistic support elements. It will recommend areas requiring development and their scope. For additional information see enclosure (1).

d. Detailed Requirements. Execute the following under this AIRTASK:

Encl.	Task Area No.	Sub-Task Plan No.	Title	Initial Est. Cost
(1)	WF41-461-408	N/A	Avionics Readiness Planning	$50,000.00

e. Material Acquisition engineers involved in providing technical support to the Project Engineer in the planning and execution of the program are listed in enclosure (1).

4. Schedule. The schedule shall be in accordance with enclosure (1).

5. Reports and Documentation.

SIGNATURE (By Direction COMNAVAIR): R. B. Nickerson — DATE: 10/17/74

CLASSIFICATION AND GROUP MARKING: UNCLASSIFIED

Previous issues of this form are obsolete.

UNCLASSIFIED

a. Technical Reports. The detailed plan shall be submitted to AIR-340E in accordance with enclosure (1). An estimated thirty-five copies will be required.

b. Task Area Plans. In preparation for investigations to be undertaken during this and ensuing fiscal years, Task Area Plans may be submitted with the detailed plan of paragraph 5.a. These should be in sufficient detail at the sub-task level to enable cognizant NAVAIRSYSCOM personnel to make an adequate appraisal. The Task Area Plans shall be submitted to AIR-340E.

c. Progress Illustrations. In order to assist AIR-340 in presenting current project status and defending budgetary requirements, 8" x 10" viewgraphs may be required illustrating work to be accomplished thru the plan. These may be illustrations of concepts, block diagrams, photographs or sketches of experimental devices, or similar technical representations. Management-type information, such as milestones and funding plans, are also desired in viewgraph form.

d. Program Reviews. Reviews shall be in accordance with enclosure (1).

6. Contractual Authority. Off-station procurement is authorized as indicated in the Proposition.

7. Source and Disposition of Equipments. Not applicable.

8. Aircraft Requirements. Not applicable.

9. Cost Estimate.

a. Total estimated cost: $50,000.00

10. Source of Applicable Funds. Funds are provided by separate funding document being issued by NAVAIR.

11. Security Requirements. Access to classified material (up to Secret) will be required. Information classified up to Confidential will be generated under this AIRTASK.

Copy to:
Addressee (15)
NAVMATDATASYSGRU, Morgantown, W. Va. 26505
NAVAIRSYSCOM, T&E Coordinator

Program Plan Development for Avionics Readiness Improvement

The Naval Air Systems Command has recently completed a study to determine the requirements for the development of the next generation of Automatic Test Equipment (ATE). The study recommended that new ATE must only be developed in conjunction with the new airborne system. To this end, a new program "Avionics Readiness" is being developed. It will include airborne system and ATE design in conjunction with all logistic elements. Avionics Readiness Improvement is defined as the increase in system availability through improved reliability, training, technical data and advanced testing techniques.

A review of technology with industry indicates trends toward more digital techniques and Built-in-Test with a potential reduction in Intermediate Level maintenance. This trend is confirmed by exploratory developments now being conducted and further reinforces the recommendation that a coordinated development program is required.

A detailed program plan for Avionics Readiness in the 1980-2000 time period is now required. The plan should define areas requiring development emphasis and provide direction for the ultimate production and fleet introduction of an integrated Avionics and Support system. The plan development should include the following considerations:

1. Technology Assessment/Forecast

Determine the direction and speed of technology growth and its impact on future systems and system diagnostics. The expected life of new technologies and the logistic impact of rapid change should be assessed.

2. Future Operational Requirements

Review long range weapon system planning to determine those programs which can be impacted by the Avionics Readiness Program. Determine potential Advanced Development Avionics Systems which will be applied to those weapon systems. Recommend funding level and distribution required for Exploratory Development in support of the selected Advanced Development Projects. Alternative approaches should be identified and prioritized.

3. Diagnostics/Maintenance

Requirements for diagnostic procedure development, packaging for maintenance and inter-system fault detection should be identified. The limitations of the program should be defined in terms of the total weapon system and its various levels (WRA-SRA).

ENCLOSURE (1)

4. Duration

The study should be completed within three months with informal reviews at the end of the sixth and ninth weeks and a formal review at the end of the study.

5. Technical Steering Group

The Technical Steering Group will be composed of:

A. B. Nehman	AIR-340
B. Poppert	AIR-340E
E. B. Beggs	AIR-360
B. A. Zempolich	AIR-360B
D. A. Rosso, Jr.	AIR-370
E. T. Hooper	AIR-370D

The plan for Avionics Readiness Improvement must show its integral relationship with the long range Avionics Development Plan being prepared currently for AIR-360-AIR-370.